This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

UC-NRLF
B 3 491 868
QE
261
A4
1920

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1920.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

LIBRARY OF THE UNIVERSITY OF CALIFORNIA
PRESENTED BY H.M. GOVERNMENT

LONDON :
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE.

To be purchased from
E. STANFORD, LTD., 12, 13 and 14, LONG ACRE, LONDON, W.C.2;
W. & A. K. JOHNSTON, LTD., 2, ST. ANDREW SQUARE, EDINBURGH;
HODGES, FIGGIS & CO., LTD., 20, NASSAU STREET, and
17 and 18, FREDERICK STREET, DUBLIN;
or from any Agent for the sale of Ordnance Survey Maps; or through any Bookseller, from the DIRECTOR GENERAL, ORDNANCE SURVEY OFFICE, SOUTHAMPTON.

1921.

Price 3s. 6d. Net.

Digitized by Google

EXCHANGE

EARTH
SCIENCES
LIBRARY

Digitized by Google

Digitized by Google

Digitized by Google

MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND THE

MUSEUM OF PRACTICAL GEOLOGY

FOR

1920.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HIS MAJESTY'S TREASURY.

UNIV. OF CALIFORNIA

LONDON :
PRINTED UNDER THE AUTHORITY OF HIS MAJESTY'S STATIONERY OFFICE.

To be purchased from
E. STANFORD, LTD., 12, 13 and 14, LONG ACRE, LONDON, W.C.2;
W. & A. K. JOHNSTON, LTD., 2, ST. ANDREW SQUARE, EDINBURGH;
HODGES, FIGGIS & CO., LTD., 20, NASSAU STREET, and
17 and 18, FREDERICK STREET, DUBLIN;
or from any Agent for the sale of Ordnance Survey Maps; or through any Bookseller, from the DIRECTOR GENERAL, ORDNANCE SURVEY OFFICE, SOUTHAMPTON.

1921.

Price 3s. 6d. Net

Digitized by Google

GE5 .
A 4
1980
EARTH
SCIENCES
LIBRARY

EXCHANGE

UNIV. OF
CALIFORNIA

Digitized by Google

CONTENTS.

PAGE

I. INTRODUCTION BY THE DIRECTOR - - - - 1

II. FIELD WORK - - - - - - - - - - - 5

(A) ENGLAND AND WALES:
1. London and South-Eastern District - - - 5
2. Warwickshire and Staffordshire District - 9
3. Shropshire District - - - - - - - 22
4. Cumberland, Westmorland and Furness - - 28
5. Northumberland and Durham - - - - 29
6. Borings for oil in Derbyshire and Staffordshire - 30

(B) SCOTLAND:
1. West Highland District - - - - - - 31
2. North Highland District - - - - - - 44
3. North Ayrshire - - - - - - - - - 48
4. Stirlingshire, Clackmannanshire, Lanarkshire 48
5. Borings for oil at D'Arcy and West Calder - 55

III. PETROGRAPHICAL WORK - - - - - - - 56
1. England and Wales - - - - - - - 56
2. Scotland - - - - - - - - - - 57

IV. CHEMICAL WORK - - - - - - - - - 58

V. PALÆONTOLOGICAL WORK - - - - - - - 62
1. England and Wales - - - - - - - 62
2. Scotland - - - - - - - - - - 65

VI. PHOTOGRAPHIC WORK - - - - - - - 65

VII. MUSEUM OF PRACTICAL GEOLOGY - - - - 65
List of Donations during the year 1920 - - - - 66

VIII. MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED 68

APPENDIX I.—The Banffshire Coast Section of the Highland Schists. By H. H. READ - - - - - 70

„ II.—Report on Sections exposed in Excavations for Sewers in the Parish of Brockenhurst, Hants. By H. J. OSBORNE WHITE, F.G.S. - - 81

„ III.—On Borings for Coal near Maryport, Cumberland. By BERNARD SMITH, M.A. - - - - - 85

„ IV.—On a Boring for Coal at Yate, Gloucestershire. By J. PRINGLE - - - - - - - - 92

„ V.—Total quantity of Tin, Copper and other Minerals produced in Devonshire, particularly with regard to the amounts raised from each Parish. By DONALD A. MACALISTER, A.R.S.M. 96

INDEX - - - - - - - - - - - - - - 103

GB

452269

Digitized by Google

ILLUSTRATIONS.

		PAGE
FIG. 1.	—Tertiary Lavas overlying a weathered knob of sandstone at Bloody Bay	37
,, 2.	—Geological Map of the Banffshire Coast	71
,, 3.	—Sites of borings near Maryport	86

Digitized by Google

UNIV. OF CALIFORNIA

SUMMARY OF PROGRESS

OF THE

GEOLOGICAL SURVEY

AND

MUSEUM

FOR 1920.

I.—INTRODUCTION.

By J. S. FLETT, M.A., D.Sc., LL.D., F.R.S.

During the year 1920 changes on the staff of the Geological Survey were exceptionally numerous and important. In July Sir Aubrey Strahan, Director, and Mr. G. W. Lamplugh, Assistant Director (for England and Wales), retired after completing their service; Dr. Flett (Assistant Director for Scotland) was appointed Director, and Mr. J. Allen Howe (Curator of the Museum) became Assistant Director in Mr. Lamplugh's place. Dr. Walcot Gibson was promoted Assistant Director for Scotland in succession to Dr. Flett, and proceeded to Edinburgh in November. Dr. McLintock, of the Royal Scottish Museum, formerly a member of the staff of the Museum of Practical Geology, was appointed to succeed Mr. Allen Howe as Curator, but did not take up his duties before the close of the year. The staff was expanded by the appointment of six geologists, and Mr. Henry Dewey and Mr. Bernard Smith were appointed District Geologists.

It was decided to begin the revision of the maps of some of the more important districts of the North of England, and to open local offices in Newcastle-upon-Tyne and in Whitehaven. Mr. R. G. Carruthers is to take charge of a field-unit, comprising four geologists, in the Northumberland and Durham district, and Mr. Bernard Smith is to superintend the work of a similar unit in Cumberland and Westmorland. By the close of the year a start had been made in the work of organising these new field-units.

In England and Wales during 1920 work was continued in all the districts in which mapping had been in progress before the war, viz., the London district under Mr. R. G. Carruthers, the Warwickshire and Staffordshire district under Dr. Walcot Gibson, and in Shropshire under Mr. T. C. Cantrill. At the same time it

x (78)14434 Wt 1394—S 8/967 650 8/21 A

Digitized by Google

was necessary to continue the investigation of the country's resources of economic minerals, which had been in progress during the previous six years, in order to complete the series of Special Reports on the Mineral Resources of Great Britain, inaugurated by Sir Aubrey Strahan, which had proved so successful. Of these the principal were a series of reports on the lead and zinc ores of England and Wales, on copper ores, and on salt deposits. At the close of the year these reports had been completed in manuscript, and were in the press or being edited for publication. Several reports on iron ores, arsenic, fireclays and siliceous refractories were published during 1920, and new editions of the reports on silica rocks and on cannel coal, mineral oil, etc., in England were issued. In all these cases a certain amount of field-work had to be done to bring the information up to date.

In Scotland field-work was continued in all the districts which were in hand before the War, viz., Ayrshire, the Central coalfield (with Clackmannanshire), Mull and the adjacent islands, and Sutherlandshire, but part of the time of the staff during the summer was taken up with special enquiries. Mr. Wilson has prepared a report on the lead, zinc and copper ores of Scotland, which involved much field-work. Dr. Lee has begun a revision of the Secondary rocks of the Brora coalfield, with especial reference to the correct determination of the palæontological zones. Mr. Macgregor has edited a report on the iron ores of Scotland, which was published during the year.

In the London district Mr. Carruthers and his staff have been at work principally in the Lea Valley, and near Crayford and Erith on the south side of the Thames. Several points of interest have been added to the information available. The Reading Beds of Collier's End show great lateral variation, which may indicate that they are unconformably overlapped by the London Clay. Near Swanscombe the Blackheath Beds are exceedingly thin, and may, indeed, be absent in places; but near Shorne they have a thickness of about 20 ft., and are apparently of normal character. The terraces of the Lea Valley have been the subject of careful study.

The Swanscombe gravels, which yield many palæolithic flint implements, are divisible into a 100-ft. terrace, and the 50-ft. deposits, of which the latter apparently form a continuous series down to the bottom of the buried channel of the Thames.

In the Midlands district (Warwickshire and Staffordshire) the solid rocks surveyed are Cambrian, Silurian, Carboniferous and New Red. A small area of the quartzite of the Lickey Hills, near Rubery, enters the Birmingham Sheet, but it has not been proved to contain fossils, and is presumptively of Lower Cambrian age. Of the Silurian rocks of this district the Upper Llandovery is represented by a fossiliferous sandstone near Rubery village. The Wenlock strata which follow, especially those of the Wren's Nest, Dudley, are well known to all geologists. They comprise the Wenlock Shales and Limestone, long quarried and now

Digitized by Google

mined. Above these the Ludlow Shales and the higher Silurian up to the horizon of the Ledbury Passage Beds have a fairly extensive development within the area surveyed during the year, especially around Turner's Hill and Ellowes Park. The Upper Carboniferous of the Dudley district comprises the Etruria Marls, the Keele Beds and the Hamstead Beds, of which the last-named contains a limestone-breccia, or calcareous conglomerate. Near Halesowen the Halesowen Sandstone contains Spirorbis limestones and three seams of coal which are not workable. The Keele Beds and Hamstead Beds, which occupy the top of the Carboniferous succession, are very typically developed, and seem to be quite conformable throughout.

The Bunter and Keuper of Newport (Salop) present some features in common, but are, on the whole, well-characterised and distinct. An unconformability probably occurs between them, but its significance is at present impossible to estimate. In the Birmingham area the Upper Mottled Sandstone assumes great importance, and has served as a source for moulding sands, which are of high reputation.

The Glacial deposits of the Midlands in the vicinity of Newport and Birmingham, though they have been very minutely investigated by many local geologists, continue to furnish results which are of great interest as a record of the closing stages of the Glacial period. Around Newport sands and gravels were deposited as series of fans, the different series marking successive positions of the ice-front. Apparently there are no terminal moraines. Eskers trending at right-angles to the ice-front connect corresponding fans in the several series. At a later stage an extensive lake covered the area up to the 300-ft. contour. Its shore-line is shown in places by terraces, but as a rule merely by a notch.

Although systematic mapping has not yet been begun in the Whitehaven district, Mr. Smith has had opportunity of examining the cores of certain bores that have recently been made. He finds that these indicate a remarkable change in the character of the Carboniferous Limestone in the vicinity of the boundary fault of the exposed Whitehaven coalfield. This was not wholly unexpected, as the surface indications had suggested a similar conclusion; but it is evident that when the mapping has demonstrated the conditions in the exposed coalfield, and further boring has taken place, important results may be anticipated.

In Scotland the field-staff were engaged during most of the summer in the primary 6-in. survey of the Highlands. New light has been thrown on the geology of Iona by Mr. Anderson, who finds that the island consists of a platform of Lewisian Gneiss overlain by Torridon sediments. In the Lewisian there are rocks of igneous, and others of sedimentary origin; among the latter are the well-known Iona marble and dark graphitic schists. Intrusive masses of epidiorite and pegmatite traverse the gneisses and schists. The basal conglomerate of the Torridon is, in

Digitized by Google

places, intensely crushed, but the common boundary of the two series is not regarded as a thrust-plane. Dykes of basalt and lamprophyre intersect the Torridon strata, and the Newer Granite of the Ross of Mull possibly produces contact alteration in these sediments.

A very interesting section at Gribun, in the Island of Mull, has now been investigated for the first time since Professor Judd described it in 1878. Many fossils have been collected, and have been determined by Dr. Lee. Trias and Rhaetic rocks form the basement, the latter yielding characteristic fossils. Broadford Beds follow (Hettangian and Sinemurian) containing well-preserved fossils, and Cretaceous rocks, including Cenomanian (Greensand). The whole sequence is interesting as affording one of the most important exposures of Secondary rocks in the island of Mull. In Ardnamurchan Mr. Richey has found a considerable outlier which is probably Inferior Oolite though it has a resemblance to Chalk.

The mapping of Mull has been completed, and the reports describe the usual variety of lavas and basic intrusions, with additional information on the Secondary rocks that underlie the volcanic plateau, and the Tertiary sediments among the lavas. The famous fossil tree of Burgh, which has been known for over a hundred years, has been very carefully described, and specimens of the fossil wood sliced for microscopic examination. Ardnamurchan, which is part of a Tertiary volcano of the same age as the mountains of Skye and Mull, has been visited by Mr. Richey, but the actual survey of the ground has hardly been begun. Staffa, famous for its basaltic pillars and caves, consists mainly of a single lava with its slaggy top covered by a thin layer of ash. One small, intrusive sill with clearly transgressive margins occurs below the base of the lava.

In Easter Ross the area surveyed consisted mainly of typical Moine gneisses intersected by lamprophyre dykes, and in the adjacent parts of Sutherland there are also granitic intrusions with allied basic masses which occasionally give rise to rocks of hybrid origin.

The igneous rocks which form the uplands around the North Ayrshire coalfield have been shown to include an extensive development of trachytic lavas overlain by basalts of Dalmeny type. These trachyte lavas may occur in two series, and are of interest because most of the trachytes of the West of Scotland have hitherto been believed to be of intrusive origin.

In Stirlingshire Mr. Dinham has brought to light an encrinital limestone which provides an important landmark in the correlation of the Carboniferous Limestones of Campsie with those of the Bannockburn district.

The Alloa coalfield of Clackmannanshire forms a link between the Central coalfield and that of West Fife. The revision is now in hand, and it is considered open to question whether the Barren Red Measures of the Upper Carboniferous occur in this area, as has hitherto been supposed.

Digitized by Google

Extensive mining developments are taking place in the Douglas coalfield, and much new information is being collected especially from bores in progress. The revision of this district is proving of great interest, and resulting in a much more correct interpretation of the complicated structure of this coalfield.

Dr. H. H. Thomas has made an investigation into the petrographical characters of the foreign stones that compose the inner circle at Stonehenge, and arrives at the conclusion that they have been transported by human agency from Prescelly Mountains in Pembrokeshire, no doubt expressly for the purpose. This seems to set at rest a question which has long interested the antiquarian, and sheds an interesting light on the importance in which the building of Stonehenge was held by the early races of Britain.

II.—FIELD WORK.

(A)—ENGLAND AND WALES.

1. London and South-Eastern District.

H. Dewey, District Geologist.
R. L. Sherlock, D.Sc., A.R.C.S.
C. E. N. Bromehead, B.A.
R. W. Pocock, B.Sc.
T. Robertson, B.Sc.
} Geologists.

In the London District the mapping, which was suspended during the war, has been continued in an easterly direction on both sides of the Thames. On the southern side, Mr. Bromehead has surveyed the ground in Sheet 271 (Dartford) extending from Erith and Crayford to the margin of the map a mile or two east of Gravesend.

Dr. Sherlock has mapped in Sheet 239 (Hertford) the area extending eastwards from Hertford to Ware and thence down the Lea Valley to Cheshunt, and a small area in Sheet 221 (Hitchin) between Woodhall Park and Sacombe. Mr. Pocock and Mr. Robertson were engaged for a few weeks mapping the ground around Goff's Oak, Northaw and Cheshunt. Some parts of the North London map (Sheet 256) have been revised by Mr. Bromehead, especially the districts of Hampstead, Holloway, Stoke Newington, Bow, and West Ham, while Mr. Pocock has revised those of Watford, Bushey and Stanmore. The work was under the superintendence of Mr. Carruthers until his transference to Northumberland in October, when it was placed in the charge of Mr. Dewey.

CRETACEOUS.

The Chalk bordering the Thames between Erith and Gravesend has been mapped by Mr. Bromehead. It all belongs to the zone

Digitized by Google

of *Micraster coranguinum*, as previously ascertained by Mr. Dibley.[1]

TERTIARY.

Dr. Sherlock records a section of abnormal Reading Beds at the south of Collier's End village (Sheet 221) in a disused brickyard. Below 8 ft. of lead-grey clay with brown mottling, which appears to be London Clay, there is a sharp plane of division. In downward succession it is followed by 3 ft. of black, somewhat silty clay, mostly stoneless, but with occasional flint-pebbles, some of which stand vertically. Most of the pebbles are black but some are yellow and others red, and a few are fragmentary. The black clay is local, being absent from a pit only 200 yds. to the west. The black bed passes down quickly, but with a sharp dividing plane, into 8 ft. of greenish-grey, sandy clay with indefinite crimson patches, which contains a few calcareous nodules. Below the clay is a stony mass of flints and flint pebbles resting on a piped surface of chalk, with the usual black or green-coated flints at the junction. Less than a mile to the east there is a 12-ft. pit in the typical fine white sand of the Reading Beds. These sections seem to indicate a rapid lateral change in the Reading Beds and an unconformable overlap by the London Clay, not previously noted in this part of the London Basin.

From Hertford to Great Amwell the Tertiary escarpment follows the right bank of the Lea, but to a great extent is buried under Drift deposits. Reading Beds, however, are visible in a pit situated in the small valley that extends from the east end of Hertford to Little Amwell. Here an 8-ft. section shows lilac silty clay, passing down into white sand with glauconite. At a higher level, behind Fox Hole Farm, an obscured brickyard appears to be in the London Clay. Across the gorge of the Lea, at Great Amwell, the Tertiary escarpment continues along the south side of the Ash, but here also it is buried under Drift.

At Great Amwell the Lea, having breached the escarpment, turns southwards and flows over the dip-slope of the Tertiaries. London Clay covers some square miles to the west of Broxbourne and Cheshunt and is mostly under plantations. On the east side of the Lea opposite Hoddesdon and Cheshunt there is a strip of bare London Clay between the river flat and the cap of boulder clay, but no sections exist on either side of the river.

In the area surveyed by Mr. Bromehead, the Thanet Sand and Woolwich Beds maintain their usual characters, but it is noticeable that Messrs. Priest and Stamp have detected fossils in the Bottom Bed near Swanscombe.[2] The same authors have described the Blackheath Beds of the Swanscombe outlier.

[1] 'Notes on the Chalk of the Medway Valley, Gravesend, etc.,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 68–105.

[2] 'Geology of Swanscombe Eocene Outlier,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 187–199.

Digitized by Google

These beds are so attenuated in this district that they were not indicated on the original 1-in. map. Even in the present 6-in. survey it has not been found possible to detect them everywhere; for example, on the west side of Swanscombe Wood the London Clay is shown as resting directly on Woolwich Beds. In the next large Tertiary outlier to the east, that of Shorne and Cobham, the Blackheath Beds reappear in force, at least 20 ft. of pebble beds and a few feet of sand being visible in sections. Here, therefore, this division has a development similar to that in the type area of Blackheath and Bexley. No cause has yet been suggested to account for its great attenuation in the intermediate area. The London Clay is the highest Tertiary formation in the district.

PLEISTOCENE.

In the area mapped by Dr. Sherlock the Chalky Boulder Clay with accompanying fluvioglacial sand and gravel covers most of the high ground. However, north of the Lea the Chalk rises to the surface between Woodhall Park and Sacombe, and the usually continuous sheet of drift is reduced to patches on the hill tops. The sand and gravel as a rule underlies the boulder clay and generally crops out in the slopes of the valleys, while boulder clay covers the plateau; but as the sand and gravel is in thick lenticles, it is absent in some parts and in others so thick that it extends on to the plateau. A large pit, south-east of Hertford, shows 5½ ft. of sand and gravel on 16 ft. of Chalky Boulder Clay, and below this about 14 ft. of sand and gravel resting on chalk. Here there is gravel above as well as below the boulder clay, and it seems probable that the clay is not the main mass, but a discontinuous band that appears sometimes below and sometimes within the gravel, as at Hertingfordbury, Watton-at-Stone, and the Ware section previously described.[1]

The fluvioglacial sand and gravel borders the Lea Valley on the western slopes from Hoddesdon to Cheshunt, and its level falls with the valley. South of the Lea, areas of clay with pockets of gravel are found on the top of the plateau at Little Amwell. They are characterised by the absence of the far-travelled pebbles, so common in the fluvioglacial gravels, and are composed mainly of flint-pebbles derived from Tertiary deposits. They contain also pebbles of white quartz and, occasionally, of Lower Greensand chert, both constituents being probably of Tertiary origin. With the gradual fall of the surface southwards the patches of clayey gravel become partially overlain by boulder clay, but they are always relatively higher than the adjacent fluvioglacial sand and gravel.

In the Lea Valley a terrace appears at Great Amwell. The northern boundary makes a feature extending across the valley and covered by fluvioglacial gravel probably marks a Reading

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, p. 31. Nos. 1 and 3 in the section there given are identical.

Digitized by Google

Beds feature. The terrace has been followed along the west bank of the Lea southwards as far as Cheshunt. Excavations in its sand and gravel show sections identical with those in the fluvioglacial deposits. The difference between them is firstly, position; and secondly, as recorded at Hoddesdon by Mr. S. H. Warren,[1] the presence in the terrace gravel of flint implements. Brickearth covers parts of the terrace and has yielded bones of mammoth, reindeer and some other animals, and flint implements. It seems probable that the terrace may prove to be of Taplow age.

At Cheshunt small areas of blue and black clay are recorded by the nurserymen where one would expect gravel. So far no sections are available, but it is not unlikely that the clay is contemporaneous with the Arctic Bed found by Mr. Warren[2] at Ponder's End, lower down the Lea.

Mr. Bromehead finds that round Darenth Wood and Swanscombe Park there are patches of "Plateau" gravel. These consist of materials derived locally and from the south, and differ markedly from the gravel of Shooter's Hill, for which a Pliocene age has recently been claimed.[3]

The river-deposits of the Swanscombe neighbourhood had been carefully investigated by Messrs. R. Smith and H. Dewey previous to the survey.[4]

Although on the Essex side of the Thames the usual three terraces can be detected and were mapped by Mr. T. I. Pocock 18 years ago, on the south side there appears to be a continuous deposit from about the 50-ft. level to the bottom of the buried channel. This deposit is best known in the Crayford-Erith area, where many deep sections have been available for study. It will probably be found advisable to designate the river-gravels of the Dartford Sheet as the "Swanscombe" and the "Crayford" terraces, the former being equivalent to the Boyn or 100-ft., and the latter to the Taplow or 50-ft., and the Flood-plain terraces.

Besides the bedded river-gravels and brickearths, there are tumultuous deposits, found in several of the valleys tributary to the Thames, consisting of chalk-rubble, gravel and brickearth. These were evidently formed at a time when the topography was approximately that of the present day, since they occur along existing stream-valleys and depend for their composition on the strata bordering the valleys. Where Chalk crops out they consist of a rubble of chalk fragments, sometimes re-cemented, to which the term Coombe Rock has been applied; in the neighbourhood of Tertiary outliers they are brickearths

[1] *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, p. 225.

[2] *Op. cit.*, pp. 213–217.

[3] Leach, A. L., 'Supplementary Notes on Geology of Shooter's Hill,' *Proc. Geol. Assoc.*, vol. xxxi, 1920, pp. 127–132.

[4] *Archæologia*, vol. lxiv, 1913, pp. 177–204; vol. lxv, 1914, pp. 187–212.

Digitized by Google

formed of re-sorted Tertiary material and with difficulty distinguished from those beds *in situ*; where patches of Swanscombe Terrace gravels occupy the high ground they are essentially gravels. The varieties of composition are so intermingled that it is impossible to map them separately, and it is proposed to include them under the term "Coombe Deposits." From the contained fossils and implements and from the manner of accumulation the period of formation appears to be the end of the Taplow stage, when the semi-arctic conditions of the Mousterian culture prevailed.

ECONOMICS.

The chief industry of geological importance is the manufacture of Portland cement. Along the river-bank from Stone to Gravesend chalk quarries for this purpose are almost continuous, and the operating companies are being forced to obtain their chalk from localities further and further inland. The Associated Portland Cement Manufacturers are also working the London Clay of Swanscombe Wood in a huge pit; the clay is made into slurry on the spot and piped to the works.

The Erith moulding sand (Thanet Sand) was worked extensively during the war, and the industry is still of great importance.

The Swanscombe Terrace gravels are largely dug for concrete-making and other purposes.

Over much of the area the Bottom Bed of the Woolwich Series is strongly impregnated with iron-oxide. There are some indications of an ancient "bloomery" working this ore in Lord's Wood, Green Street Green.

2. Warwickshire and Staffordshire District.

W. Gibson, D.Sc., District Geologist.
E. E. L. Dixon, B.Sc., A.R.C.S.
T. Eastwood, A.R.C.S.
T. H. Whitehead, B.Sc., A.R.C.S.
T. Robertson, B.Sc.
} Geologists.

During the past season, work in the Stafford Sheet (139) and in the north-western part of the Wolverhampton Sheet (153) has been continued by Messrs. Dixon and Robertson in the neighbourhood of Newport, Stone and Stafford. In the Dudley Sheet (167) Mr. Whitehead has mapped part of the mining district and its western border, lying between Tipton, Cradley and Kingswinford; while in the Birmingham Sheet (168) Mr. Eastwood has surveyed the south-western suburbs of that city and the ground extending westward towards Halesowen.

Digitized by Google

CAMBRIAN.

The oldest rocks in the district examined by Mr. Eastwood are the Cambrian quartzites of the Lickey Hills, the northern portion of which falls, at Rubery, within the Birmingham Sheet. The mass consists of quartzite, similar to that of Hartshill, near Nuneaton. The beds strike approximately north-and-south, *i.e.*, parallel to the ridge, though the dip is very inconstant. Neither the top nor the bottom of the quartzite is exposed, and so far the quartzite has yielded no fossils; but on lithological grounds the Lickey Quartzite is regarded as of Lower Cambrian age and equivalent to the Park Hill and Tuttle Hill series of Warwickshire.

SILURIAN.

The Lickey Quartzite is succeeded unconformably by sandstones, varying from a grey-white compact rock, very like the underlying quartzite in appearance, to open-textured reddish sandstone, occasionally calcareous. The basal bed frequently contains boulders and pebbles of the underlying quartzite, as may be seen in the quarries on the south side of the main road in Rubery village. Casts of fossils are fairly abundant, and establish the age of the sandstones as Upper Llandovery. Up to the present, Tarannon Shales have not been found in this area, and the Llandovery Sandstone appears to be succeeded at once by shales, clays, and mudstones, with thin bands of limestone, and by compact sandstone, all referable to the Barr or Woolhope Beds of the Wenlock. The only section in them is that afforded by Callow Brook, the stream in the Asylum grounds at Rubery, where they pass beneath the Halesowen Beds of the Upper Coal Measures.

The outcrops of Silurian rocks at the Castle Hill and at the Wren's Nest, Dudley, and at Turner's Hill near Sedgley (Sheet 167) have been surveyed by Mr. Whitehead. Of these, the lowest beds occur in the cores of the Castle Hill and Wren's Nest domes, and consist of Wenlock Shales. These are followed by the well-known Wenlock or Dudley Limestone, which consists of two bands separated by flaggy and nodular limestones and mudstones. Both these bands have been almost completely quarried away at the outcrop, though mining for the limestone still continues. The Lower Ludlow Shales, consisting of mudstones with bands and nodules of limestone, succeed the Wenlock Limestones. At Dudley the area occupied by the outcrop of these beds has been found to extend farther south than is represented on the geological maps hitherto published. They occupy the surface in the allotments south-west of the Priory, near the Grammar School, and in the grave-yard of St. James's Church, Eve Hill. In an exposure in a ditch to the west of the Grammar School playing-field the dip is south-west, whilst to the east of the playing-field it is east or a little south of

Digitized by Google

east, indicating an approach to the southern termination of the Wren's Nest dome.

Mr. John Hughes has supplied details of a shaft and bore-hole sunk within the site now occupied by the Dudley Union Workhouse. The following is an abstract of the section :—

		Ft.	in.
Measures to top of Fireclay Coal		54	4
Fireclay Coal		2	0
Rock, batt, clod, etc.		24	9
Bottom Coal (four coals with partings)		10	0
Fireclays, binds, rock, etc.		57	6
Mottled ground		3	6
Red ground	Borehole	4	6
Red rock	Borehole	5	6
Red parting	Borehole	0	6
		162	7

It is possible that the mottled and red measures at the base of the section may be Ledbury Passage-Beds. If this is the case, the Aymestry Limestone must lie at no great distance from the surface between the Workhouse and the Wren's Nest. This section may be compared with that of the Trial Pits at Shaver's End, referred to by J. B. Jukes,[1] where 68 ft. of measures were found between the Bottom Coal and a blue clunch believed to be the top of the Silurian.

At Turner's Hill and Ellowes Park the following beds are exposed :—

6. Ledbury Passage-Beds.
5. Temeside Shales.
4. Downton Castle Sandstones.
3. Upper Ludlow Shales.
2. Aymestry Limestone.
1. Lower Ludlow Shales.

Of (1) only a small portion is poorly exposed in a little quarry on the west side of Turner's Hill. The Aymestry Limestone (2) is exposed in the same quarry, and contains the characteristic fossil, *Conchidium knighti*, represented by small individuals. The outcrop of the limestone extends only a few yards to north and south of the quarry, being truncated in both directions by faults. Both (3) and (4) are poorly exposed in the western scarp slope and near the summit of the hill; whilst (5) was recognised from the fragments ploughed up in a field immediately to the south-east of Turner's Hill Wood. A bed believed to be one of the Temeside Bone-Beds was found in place in the ditch forming the southern boundary of this field. In the adjoining field to the south large fragments of highly micaceous, purple

[1] 'The South Staffordshire Coal-Field' (*Mem. Geol. Surv.*), ed. 2, 1859, p. 83; also *Vert. Sect.*, Sheet 18, No. 36.

Digitized by Google

and green sandstones belonging to the Ledbury Passage-Beds (6) were found, thrown up by the plough. The Passage-Beds crop out in Ellowes Park also, and are well exposed in an east-and-west stream-course near Ellowes Park Farm.[1]

CARBONIFEROUS : COAL MEASURES.

Near Dudley, on the western margin of the South Staffordshire coalfield, the delimitation of the outcrops of the Middle Coal Measures, and of the various members of the Upper Coal Measures, has been continued by Mr. Whitehead.

The Etruria (Old Hill) Marls occupy the higher ground around Brierley Hill and Scott's Green, and are brought in by the Brierley Hill fault-trough. They also extend northward along the western margin of the exposed coalfield from the junction of the Brockmoor and Western Boundary faults at Brettell Lane nearly to Straits Green, the boundary of their outcrop to the east being determined largely by the Brockmoor and Shut End Faults. In general the Etruria Marls of this part of the coalfield appear sandier, and the marls of a duller purple colour, than around Old Hill and Oldbury.

The Halesowen Beds are nowhere preserved in the area surveyed, with the possible exception of some coarse greenish sandstones exposed in the brook north of Conqueror's Farm, Straits Green. If, as their characters suggest, these beds belong to the Halesowen group, they must be bounded on all sides by faults, as they abut, on the west against the upper portion of the Keele Beds, and on the east against the Middle Coal Measures.

The Keele Beds occupy the eastern half of Himley Park, and near the Straits form a shelf-like feature between the high ground formed of the Hamstead Beds to the north-west and the Western Boundary Fault to the south-east. They consist chiefly of red marls and sandstones, a 'pellety sandstone' or limestone breccia (conglomeratic cornstone) occurring in the cutting of the mineral railway in Himley Wood. There are at present insufficient data to determine what proportion of the Keele group is present at the outcrop in this area, or to establish the local thickness of the group.

Hamstead Beds.—These beds,[2] consisting of a lower Calcareous Conglomerate Group and a higher Breccia Group, occupy a strip of ground extending from near Kingswinford to Brettell Lane. The outcrop is bounded on the east by the Western Boundary Fault, and is separated from the Trias on the west by another fault. Only one band of calcareous conglomerate is recognisable, of which exposures occur north of Bromley Lane and near Buckpool. Another area of the Calcareous Conglomerate Group, with three conglomeratic horizons, comes in

[1] W. W. King, *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 2, 1917, p. 92.

[2] W. W. King, *Quart. Journ. Geol. Soc.*, vol. lv, 1899, pp. 112–115.

Digitized by Google

above the Keele Beds near the Straits, and the examination of these, together with the overlying Breccia Group, has been begun around Baggeridge and Gospel End.

North of Halesowen, in ground mapped by Mr. Eastwood, a small tract of highly-inclined Middle Coal Measures, including members of the Thick Coal, with the Gubbin Ironstone and the Heathen Coal, is being worked by a day-hole at Cockshot Lane, south-west of Blackheath. The ground is obscured by drift, and apart from the small coal-workings there are no exposures, though it is evident, since the Halesowen Beds come on east of Cockshot Lane, that a fault, described by Jukes as the Russell's Hall Fault, must intervene, as shown on the old 1-in. map (62 S.W.). The succession as far west as the Dudley canal is regarded as normal—the strata exposed at Coombes Wood Tube Works are believed to belong to the base of the Etruria Marls—though another fault, with a westward downthrow, may come in beyond, introducing beds half-way up in the Etruria Marls.

South of Halesowen there has been no exploration in the concealed coalfield since the Manor Pit was abandoned many years ago. The coals are believed to deteriorate rapidly in a southward direction.

The Etruria Marls call for little comment. Beds high in the succession are exposed in the brick-pits north-east of Halesowen station, where they consist of the usual dull-red marls and conglomerates (espley rocks), with occasional thin bands of coal. Good sections in espley rocks may be seen on Mucklow Hill, where the Russell's Hall Fault brings them against the Halesowen Sandstones.

The Halesowen Sandstones consist of sandstones interbedded with clays and shales, including thin seams of coal and at least two bands of Spirorbis limestone. When fresh, their prevalent colour is grey, though the sandstones usually weather buff or brown and are occasionally stained red, while the argillaceous beds range from white to almost black. The beds are sometimes olive- and chocolate-coloured, especially at the base and near the top of the group. The sandstones are occasionally both pellety and pebbly; the latter condition is especially marked in the basal sandstone, which in places so closely resembles an espley rock of the Etruria Marls that it is difficult to distinguish between the two groups.

The Spirorbis limestones of this group are grey or dirty white in colour, in contrast with the blue and blue-grey limestones of the overlying Keele Beds. The lowest limestone in the Halesowen area was at one time worked about 400 yds. east of Manor Farm, and apparently occurs as a flaggy band, 8 ins. to 1 ft. in thickness, immediately above a bed of sandstone. The same band is represented by debris on a dump from an air-shaft to the canal-tunnel at Lapal House, Moor Street. Its position in the Halesowen group is about 100 ft. above the base. During the excavation of the sewers for some new houses between Hayley Green

Digitized by Google

and Hasbury (south-west of Halesowen) a similar bed was encountered. There *Spirorbis pusillus* was abundant and of unusually large size. In addition to the characteristic fossil, spines and scales of a fish of Acanthoid type are present, along with fragments of coal.

Higher in the succession, and probably not more than 150 ft. below the top of the Halesowen group, is another Spirorbis horizon. This may be seen *in situ* in a little tributary 300 yds. south of Illey Mill. The limestone is an 8-in. band of compact rock lying in a thin belt of clays between two sandstones, the lower of which is exposed in the brook by Illey Mill. Although the rock as a whole is compact, it is frequently made up of fragments of white limestone set in a matrix of grey limestone of equal hardness. *Spirorbis* is not abundant, but it occurs in both matrix and fragments. The locality mentioned above was first discovered by Dr. W. Gibson, and was afterwards described by the late Prof. Lapworth. During the past season, pits yielding fragments of similar limestone have been discovered between Illey Brook Farm and Illey Hall Farm. What is believed to be the same bed occurs in place in a ditch 200 yds. north-east of Warstone Farm near Lower Illey.

Several seams of coal occur in the Halesowen group, but as a rule they are very thin and impersistent. Attempts to work one or other of them have been made at the northern end of Offmoor Wood (Sheet 167); also near Rubery, and at California, but without success.

Sections in various portions of the sequence may be seen in the streams flowing northwards near Halesowen; but east of that town much of the ground is obscured by drift. Near Rubery, intermittent sections showing sandstones, clays, and coal, may be seen in the stream at Balaam's Wood, and in Callow Brook in the Asylum grounds. Recent excavations at the north end of the Asylum (Rubery Hill) exposed a seam of coal about a foot thick, associated with grey clay containing small fragments of fossil wood, and dipping westward off the Llandovery Sandstone.

The red rocks succeeding the Halesowen Sandstones and unconformably overlain by the Trias were originally classed as 'Permian of Salopian type.' In the South Staffordshire district, as in other areas in the Midlands, it is becoming increasingly clear that the whole of these beds must be relegated to the Carboniferous System. They consist of argillaceous and arenaceous sediments in which red is the prevailing colour, and the lower portion is characterised by occasional bands of bluish Spirorbis limestone. It is to this group that the name Keele Beds is applied.

The junction of the Keele Beds with the Halesowen Sandstones appears to be conformable, and the base is frequently marked by sandstones of dark lavender tint, such as are seen in Breach Dingle, near Romsley. These are succeeded by red

Digitized by Google

marls and sandstones with thin bands of bluish limestone containing occasional specimens of *Spirorbis*. The band found by Mr. Cantrill[1] near Wassel Grove and believed to be about 50 ft. above the base of the group has not been located in the Romsley area. Another band, about 350 ft. above the base of the group, first discovered by Mr. Cantrill (*op. cit.*) near Offmoor Wood, may be seen in a fragmentary condition in a gully 200 yds. north-east of St. Kenelm's Hall, and in Breach Dingle at a point 400 yds. north-north-east of St. Kenelm's Rectory, while it is abundantly represented in the debris from the pipe-line of the Birmingham aqueduct (Elan supply) at the south-east corner of Offmoor Wood. What is possibly the same band has been recorded at Frankley reservoir, and it has since been seen in Egghill Dingle, Long Kettles Wood, near Gannow Green, at Hollymoor Asylum, and near Bartley Green.

Hamstead Beds.—Higher in the succession, the marls occasionally take on an even brighter red tint than usual, whereas the sandstones, although often red, are frequently brown or yellowish. In addition to change of colour these sandstones locally become markedly calcareous and highly charged with small rolled pellets of inorganic limestone, in addition to which occasional small fragments of organic limestone, calcareous mudstone, and other foreign matters occur. In the past these conglomeratic 'cornstones' were burnt for lime. Though similar rocks are found in the Keele Beds below, the position and general characters of the main belt of these calcareous sandstones link them up with the limestone conglomerates of the Hamstead Beds, found farther north at about the same position in the sequence.

Though the Hamstead Beds, which occupy an intermediate position between the Keele Beds and the trappoid breccia of the Clent Hills, are well exposed in natural sections near Romsley, they make much more striking features around Frankley, where they are surmounted by a capping of breccia—the outlier of Frankley Beeches.

The Clent Breccia has been so well described by Mr. Wickham King[2] that there is little to add here. Up to the present the evidence is in favour of general concordance between the breccia and the beds below, while the relation between it and the overlying Trias is one of marked unconformity.

Though giving rise to prominent features, it is, as a rule, not well exposed, especially in the main mass forming the high ground extending from the Clent Hills to Rubery. In the detached areas good road-sections are to be seen at Merritt's Hill near Northfield, and in the Halesowen-Birmingham road east of Quinton. In addition to the localities already known, a small outlier of the breccia has been found north-west of Bromwich

[1] *Geol. Mag.*, 1909, p. 449.
[2] *Quart. Journ. Geol. Soc.*, vol. lv, 1899, p. 97.

Digitized by Google

Wood, between Frankley and Bartley Green. It is about 400 yds. in length by 200 yds. in breadth, and probably does not exceed 20 ft. in thickness. Though there are no sections in it, the ditches and the debris on the ploughed fields afford ample evidence of the presence of breccia.

TRIAS.

In the district of Newport (Salop) Mr. Dixon finds that, as elsewhere, the several lithological types on which the original classification of the Trias was based are not rigidly confined to the subdivisions named after them. Thus, mottled and brick-red soft sandstones, devoid of fragments of old rocks, and indistinguishable from the beds that make up the Lower and Upper Mottled subdivisions of the Bunter, are found also in the Pebble Beds and in the Keuper Sandstones. Thick beds of massed pebbles are certainly confined to the Pebble Beds; but scattered pebbles, and, more especially, subangular fragments of hard rocks, occur in the higher part of the Lower Mottled subdivision, and still more frequently in the Keuper Sandstones. The same features characterise special lithological types. In parts of the Midlands, fresh pink felspars, in the form of small worn crystals and cleavage-fragments, distinguish the base of the Keuper Sandstones from higher zones and also from Bunter beds; but near Newport such felspar-fragments occur also at various horizons in the latter formation.

Notwithstanding a community of character, in this district Bunter and Keuper are quite probably unconformable. Fortunately the junction is exposed at several places along the bold feature caused by the erosion of the soft Upper Mottled sandrock below the hard Keuper sandstones; in all sections it is either obviously or possibly sharp, and in some is uneven. Also the base of the Keuper is usually conglomeratic, though the fragments may be scattered sparsely along a single line. It has not been possible to determine variations in the thickness of the Upper Mottled formation, but that of the Keuper Sandstone varies from about 20 ft. near Broad Hill, east of Newport, to 400 ft. west of Blymhill; while a boring for water now being put down near Ivetsey Bank has proved 600 feet without reaching the base. The thinning near Newport may be due to overlap of basal members, present at Blymhill and Ivetsey Bank, by higher members, in which case the base, in places at least, is unconformable. Further evidence, however, is needed owing to an uncertainty as to the significance of variations in character and thickness in 'continental' formations such as these, and the known frequency and persistence of horizons of contemporaneous erosion in such formations.

Near Stone, Mr. Robertson finds that the Bunter Pebble Beds with their pebbly sandstones cover the area around Swynnerton, with the exception of a narrow band of Keuper

Digitized by Google

Sandstone and Marl, thrown down along the eastern side of the Apedale Fault. Another fault, running east-north-east through the middle of Swynnerton Park and thence by Darlaston and Oulton to Moddershall, throws down Keuper Marl to the south. An inlier of the Keuper Sandstone occurs in the valley of the Scotch Brook, north-east of Stone.

A strip of Pebble Beds runs south-east from Moddershall to Cotwalton. Here, as to the north, in the Stoke-on-Trent Sheet (123), the Pebble Beds seem to be directly overlain by Keuper Marl.

From Swynnerton Park for 8 miles southward to Haughton, dark red and purple Keuper Marl, usually without skerry-bands, is the only 'solid' rock to be seen. Except close to the boundary-fault at Swynnerton Park it is practically horizontal. Good exposures are visible in many places, the higher ground being for the most part free from drift.

Butterton and Swynnerton Dyke.—It has long been known that an igneous dyke cuts the higher parts of the Coal Measures on the southern margin of the North Staffordshire coalfield and extends southwards through the Triassic rocks to the west of Stone.[1] In the southern part of its course this dyke has now been traced in detail by Mr. Robertson from Swynnerton to Heamies Farm near Norton Bridge—a distance of about 3 miles. Its approximate position was detected on Pebble Bed ground just north of Swynnerton village. Thence it bears a little east of south, past the west side of Swynnerton Hall and through Swynnerton Park. Halfway through the park the outcrop is shifted about 150 yds. to the east-north-east, just where the fault already mentioned as throwing down the Keuper Marl is estimated to cross the ground. Whether this shift is due to a displacement of the dyke by the fault or to a diversion of the dyke along the fault is not known.

A short distance north of the fault a poor exposure in a coppice shows the dyke in contact with and enclosing pieces of Pebble Bed (Bunter) sandstone. In Doles Coppice, 150 yds. south of the fault, the dyke (or one branch of it) is 3 to 4 ft. thick, seems to be nearly vertical, and is seen in contact with Keuper Marl.

South of this point the dyke-outcrop traverses no other formation. It appears to run undisturbed to Pilsen's Wood, west of the Highlows, where in one place it has broadened out to an estimated width of over 100 yds. Some of the hand-specimens obtained here exhibit a much more coarsely crystalline texture than any noticed farther north. There are also exposures of much-decomposed material a short distance south of the wood. Nothing more of it is seen *in situ* until we reach the north side of the hill on which Heamies Farm is situated. Here three distinct branches of the dyke are visible, approximately in line

[1] 'The Geology of the Country round Stoke-upon-Trent' (*Mem. Geol. Surv.*), ed. 2, 1905, p. 55.

Digitized by Google

with the exposures farther north. Each of these branches is 3 to 4 ft. in thickness, with a very steep dip to the west. The most easterly and most westerly branches are respectively about 24 ft. and 240 ft. from the middle one. South of this point the dykes either thin out or cease to be traceable.

West of the South Staffordshire coalfield, from Wordsley to Himley, Mr. Whitehead finds that the Trias outcrop is divided into irregular blocks by a system of faults that would seem to be the result of adjustments accompanying, or following, the movement along the Western Boundary Fault. A borehole for water at Stourbridge Workhouse,[1] begun in the Upper Mottled Sandstone, reached the Pebble Beds at a depth of about 130 ft. As the base of the Pebble Beds on Cooknell Hill, to the south, is well over 300 ft. above sea-level, it is clear that, immediately to the south of the workhouse, there is a fault that throws the Upper Mottled Sandstone on the north against the Pebble Beds and Lower Mottled Sandstone on the south. This fault appears to run westward to the Pebble Bed escarpment at Lawneswood, where it may join a north-and-south fault, with westward downthrow, known as the Stapenhill Fault. East of this fault, and south of the 'Workhouse Fault,' the ground is occupied mainly by the Pebble Beds, the Lower Mottled Sandstone emerging in small patches against the faults to the east and west. North of the Workhouse Fault, around Kingswinford, Wall Heath, and Himley, the Upper Mottled Sandstone occupies most of the area, the Pebble Beds emerging at the Ridge Hill, at Kingswinford, in Himley Park, and in small patches brought in by faults.

Both the Upper and the Lower Mottled Sandstone seem uniformly brick-red in colour in this district, the 'mottled' character appearing only when the passage into the Pebble Beds is approached.

The Triassic rocks examined by Mr. Eastwood in the Birmingham area consist of the Bunter Pebble Beds, the Upper Mottled Sandstone, the Lower Keuper Sandstone, and the Keuper Marls.

The Bunter Pebble Beds form a continuous belt between Smethwick and California near Harborne, but much of the ground is obscured by drift. From California southward nearly to Northfield they are cut out by a fault that brings in Keuper Sandstone against Keele and Hamstead Beds; but they come in again between the latter place and Rednal. On the north, shingle-beds are abundant; but on the south the bulk of the formation consists of soft red sandstone with occasional small pebbles.

The Upper Mottled Sandstone, which has furnished considerable quantities of moulding sand in Birmingham, may be seen at several places around Hockley and Summer Hill. Until just recently the sand was also obtained from a pit in Dale Street,

[1] Information from Mr. W. Wickham King.

Digitized by Google

Smethwick, a locality much farther west than this formation is represented on the old 1-in. map (62 S.W.).

The Keuper Sandstone forms the higher ground of Birmingham and extends beyond the southern margin of the area mapped. Permanent sections are rare; but the formation may be seen in the canal-cutting south of the city, also near Weoley Castle, around Northfield, and in the Cofton railway-cutting. As a rule the sandstone is harder and browner than the Bunter, and can thus be distinguished from the rest of the Triassic sandstones; but in some cases red pellety sandstones similar to those of the Keele Beds render identification of poorly-exposed portions rather doubtful.

The Keuper Marl may be seen in numerous brick-pits to the east and south-east of Birmingham; but the actual junction with the Keuper Sandstone is not visible on account of a fault the existence of which has been proved by borings.

GLACIAL.

In continuation of the work commenced last year (1919) in the Newport (Salop) district, Mr. Dixon has found it possible to distinguish between the deposits of sand and gravel formed when the whole area lying below the 300-ft. contour was flooded beneath the waters of an ice-dammed lake and those earlier ones thrown down or laid bare as the ice-front retreated across the district. Last year some of the latter were attributed to escaping lake-waters. It is more probable that all the eskers and fan-like or delta-form deposits have originated in the ways suggested in the case of certain similar formations elsewhere, viz., that the fans and deltas have been thrown down along the ice-front at the mouths of englacial or subglacial streams during pauses in the retreat, and that the eskers show the courses of the streams. The eskers may have been formed at the mouths of the streams during the periods of more rapid retreat, or they may have accumulated in the stream-channels within the ice and have been merely bared by the retreat. The evidence obtained about Newport is open to either interpretation, but as regards the broad outline of the hypothesis it is unequivocal. The fans and eskers fall naturally into several linear series, each of which may be compared with a string carrying a few beads—the fans. With few exceptions any fan in a series is represented by a similar fan in each of the other series, and these similar fans are found to be so placed that the line connecting them, which according to the hypothesis gives us the position of the ice-front during their deposition, agrees with that position as inferred from the forms and orientations of the fans. Further, in several cases fans are bordered by hollows or by dry channels draining away from them, which seem to demand for their explanation torrents of water pouring off the fans.

The longest, widest, and most continuous of the series that have been recognised up to the present enters the southern

Digitized by Google

margin of the area examined at Blymhill, 5 miles south-east of Newport, and follows a north-westerly course past that town, where it skirts the northern end of the high Bunter ground bordering the Coalbrookdale coalfield, to leave the area at Lane End, a run of 10 miles. This series, by its continuity and the obvious resemblance of two of the swellings along it to deltas or fans, gives the clue to the interpretation of the whole. Several small series run almost due west into it, or may be said to branch to the east from it.

The other bands that have been recognised, three in number, lie to the north-east of the major series, and parallel to it, the farthest removed following a line through Littleworth, High Offley, and Knighton (5 miles north-east of Newport). They pass up and down hill in the manner characteristic of eskers.

South of the latitude of Newport these minor series cannot be traced, and the swellings noticeable along the major series, indicative of pauses in the ice-retreat, are small and ill-defined. But at Aqualate Park, Newport, and thence east-north-eastward for 4 miles to Prospect Hill, Knightley, a line of fans in all the series points to a marked pause when the ice-front reached that line. At a mile or so to the north-west another line of fans shows that the retreat was stayed still longer when a line through Chetwynd Park and Littleworth was reached. The fan thrown down during this pause by the main stream is the largest and best example in the district. The alignment of the ice-front during this pause was appreciably more north of east than during the preceding pause. A third pause is marked by a line of smaller fans between Lane End and Knighton, and further swinging-round of the ice-front is proved by the north-north-easterly trend of the line.

Though the lines of fans mark stationary positions of the ice-front, they are quite unlike the 'terminal moraines' that have been recognised in various other regions. In fact it is noteworthy that the deposits at the stationary ice-front have been almost entirely localised to a few places where streams have debouched.

The ice-dammed lake that at a later period covered the area up to the 300-ft. contour has left traces of its shore-line in the form of terraces of sand and gravel, and, much more commonly, in a more or less marked notch or change of slope. Its western and northern limits have not been found; eastward it had a small overflow at Gnosall into the Trent basin. Deposits of laminated clay have been found at many places within its area, but appear to be connected with the fans of the earlier period previously described. They may have been laid down in small temporary sheets of water held up between the ice and the high ground during the retreat across the district.

North of Stone Mr. Robertson finds that the Trent valley is lined with boulder-clay, of unknown thickness, over which

Digitized by Google

gravels rise to a height of about 30 ft. above river-level. Valley-gravels are well developed along the Trent and Sow valleys.

The Sow basin, north of Stafford, shows extensive stretches of gravel and sand, but very little boulder-clay. The broad pre-Glacial valleys have been nearly filled with sand and gravel brought down by the streams in late-Glacial or early post-Glacial times, when an enormous quantity of water was flowing. This sand and gravel collected in the side valleys also, *e.g.*, along Gamesley and Doxey Brooks. The modern shrunken rivers now run in approximately the same channels, but beyond the alluvium a slope, often steep, and sometimes 20 ft. or more in height, marks the edge of a sand and gravel terrace. These terraces are well marked along the Sow valley and are sometimes very persistent, *e.g.*, between Great Bridgeford and Stafford. The Sow now meanders over a flat peaty alluvial plain, beyond which on either side a bank of sand and gravel rises and masks with its irregular surface the contours of the original pre-Glacial valley.

An interesting channel, probably of glacial origin, is to be seen in the valley of Scotch Brook north-east of Stone. Just south of Oulton Mill the stream, which runs in a narrow steep-sided valley of Keuper sandstone, turns sharply to the west. About 200 yds. farther on it turns southwards again, round the end of a Keuper sandstone cliff. On the outer side of the first bend the valley widens out a little, and a series of clays, sands, and gravels has been deposited on the side of the sandstone slope to a height of about 30 feet above the present stream-level. There would appear to have been a block at this point, due either to the narrowness of the gorge below or to the fact that the valley beyond had not up till that time been excavated sufficiently deeply.

Overflow probably took place first of all due southward over the top of the sandstone barrier, behind which there is much gravel on the southern slopes. Finally, however, the gorge would be excavated sufficiently to allow the whole discharge to pass through it, leaving the sands and clays banked up at the side of the entrance.

No traces of drift have been found in that part of the South Staffordshire coalfield surveyed by Mr. Whitehead during the past season. To the west of the coalfield the most conspicuous drift feature is the 'esker' near Kingswinford, described by Prof. W. S. Boulton,[1] which extends, within the area surveyed, from Wordsley to Wall Heath. It forms in places a marked ridge. Exposures in it show sand and gravel, false-bedded, and sometimes contorted; with lenticles of clay, and streaks of carbonaceous material in places. In a sand-pit at Wall Heath, these sands and gravels may be seen resting on horizontal Upper Mottled Sandstone, the surface of which slopes westward at about 10°.

[1] *Proc. Birm. Nat. Hist. and Phil. Soc.*, vol. xiv, pt. 1, 1916, p. 25.

Digitized by Google

South of the River Stour, and west of the gap made by that river in the Pebble Bed escarpment at Bell's Mill, south-west of Wordsley, a patch of sand, with lenticles of gravel containing many far-travelled pebbles, lies on the Lower Mottled Sandstone at the level of the adjacent canal. North-west of Himley, clay, or sandy clay, with many pebbles, occupies much of the higher ground, and is exposed to a thickness of about 15 ft. in a cutting of the new Wolverhampton Railway north-west of Himley Plantation.

The fields between Himley and Wall Heath are plentifully strewn with pebbles, of which a certain proportion consist of basalt, and of Coal Measure grits.

Much of the solid rock around Birmingham, in Mr. Eastwood's district, is obscured by drift. West of Warley and towards Halesowen the deposit is thin, and consists of clay and sand with some stones; but eastwards thick deposits completely hide the outcrops of the Trias. From Smethwick through Harborne to California the drift has a thickness of about 80 ft. Though the Glacial deposits are extremely variable, their general succession appears to be : (1) a lower series of tough reddish clays (as seen at California), associated with bedded sands and gravels; (2) an upper series of sands, clays, and loams, mainly unbedded. Far-travelled erratics occur in both series, and include many igneous rocks similar to those of the Arenigs; while of those from a less distant source the Rowley basalt is the most readily identified. Fragments of local sedimentary materials, such as espley rock from the Etruria Marls, and sandstone from the Halesowen and Keele Beds and from the Trias, are also common; while in the Longbridge area Lickey quartzite and Llandovery sandstone are present. The former wide-spread distribution of the drift is probably implied by the presence of erratic boulders over the Romsley area, though that district is now practically free from other forms of drift.

3. Shropshire District.

T. C. Cantrill, B.Sc., District Geologist.
R. W. Pocock, B.Sc. } Geologists.
D. A. Wray, B.Sc. }

During the past season the re-survey of Liverpool and its inner suburbs, begun[1] in 1914 but suspended during the war, has been completed by Mr. Wray. The whole of the Liverpool Sheet (96), with the exception of the area occupied by rocks older than the Coal Measures, has now been revised.

In the Wem Sheet (138) the south-western portion around Baschurch, Middle, and Leaton, has been finished by Mr. Wray, while Mr. Pocock has mapped a wide belt of ground between Wem and Hodnet.

[1] 'Summary of Progress for 1914' (*Mem. Geol. Surv.*), 1915, pp. 11, 12.

Digitized by Google

In the Shrewsbury Sheet (152) the north-western margin, traversed by the Severn between Shrawardine and Shrewsbury, has been examined by Mr. Wray.

TRIAS.

In the Liverpool district the 'solid' formations mapped by Mr. Wray are the Pebble Beds and the Upper Mottled Sandstone of the Bunter, and the Basement Beds and Waterstones of the Keuper.

Considerable modification of the original map has been necessary in some parts of the district. Thus the valuable information obtained during the construction of the new outfall sewer[1] from Walton to the Canada Dock fully confirms the original contention ('Summary of Progress for 1914,' p. 11) that the broad belt of Upper Mottled Sandstone shown on the old 1-in. map (79 N.E.) between Walton Hall and Sefton Park is not present. It has also enabled Mr. Wray to locate precisely the position of the main north-and-south faults that traverse the Triassic rocks of Liverpool; and also the base of the Keuper Sandstone, which was found to rest unconformably on the Bunter Sandstone in the tunnel-section under Oriel Road.

The Pebble Beds are well exposed in numerous old quarries at Everton, Aigburth, at West Derby, and also in the extensive cutting on the L. & N.W. Railway at Olive Mount. In the Liverpool District these beds are remarkable for their uniformity.

The Upper Mottled Sandstone consists of soft mottled yellow and red sandstone, and calls for little comment.

The Keuper Basement Beds, wherever exposed, have a gritty sandstone at their base. In the re-survey they have been met with in numerous places at the southern end of the city, and their outcrop has been found to be broken up by numerous parallel north-and-south faults, some of which are visible in the cuttings on the Cheshire Lines Committee's railway to the north of Toxteth and Harrington Docks.

The only exposure of the Waterstones is a narrow faulted outcrop in St. James's Cemetery.

In the south-western part of the Wem Sheet and in the north-western margin of the Shrewsbury Sheet, surveyed by Mr. Wray, it appears that, with the exception of about 2½ square miles on the east of Middle and the north of Pim Hill (an area almost free from drift) the 'solid' geology is largely obscured by a thick mantle of Glacial deposits.

The 'solid' formations mapped are the Bunter Sandstones, the Keuper Basement Beds, the Waterstones, and the Keuper Marl.

The Lower Mottled Sandstone was examined in sections alongside the River Severn at Ford, and also in the village of Ford, where it consists of thinly laminated and fine-grained red sandstones.

[1] The results of the examination of this section are published in *Proc. Liverp. Geol. Soc.*, 1915–1916, pp. 238–251.

Digitized by Google

The Bunter Pebble Beds form an outlier at Benthall Cross and Whiston, about half a mile west of Ford. This outlier is shown on the old map (61 N.W.), but has been proved by sections exposed at Benthall Stone to cover a much larger area.

From what is known of the general structure of the district, the Pebble Beds should crop out beneath the broad covering of drift between Nesscliff and Pim Hill on the north, and Ford and Shrewsbury on the south; for the Lower Mottled Sandstone is exposed around Ford, and the Upper Mottled Sandstone on the lower slopes of Nesscliff and Pim Hill; but they were nowhere met with.

The harder beds that characterise the top of the Bunter and have been extensively quarried near Middle (at Webscott, Harmer Hill, and Pim Hill) strongly resemble beds met with in the Ruyton and Nesscliff districts farther west ('Summary of Progress for 1915,' p. 9). In like manner they give rise to a prominent feature in the landscape. They are, however, overlain by white and yellow sandstones, which appear to occupy the same horizon as the Grinshill freestones farther east, and to belong to the Keuper rather than to the Bunter. In the area about Middle the base of the Keuper has, therefore, been taken at the base of these yellow freestones.

It seems highly probable that the harder, dull-red freestones worked in the Ruyton and Nesscliff district represent not only these yellow freestones, but also part of the Upper Mottled Sandstone. As no definite line could be taken as the base of the Keuper at Ruyton and Nesscliff, the dull-red freestones have been mapped as a separate subdivision, and named the Ruyton Sandstones.

Through the whole area the Waterstones are represented by marly and flaggy chocolate-red and yellow sandstones, frequently characterised by small hollows or pores, of the size of a pin's head or of a pea. They are well exposed at Balderton Hall near Middle, and also near the National Schools and Shotton Hall, in the Harmer Hill district.

The Keuper Marl is well exposed in large disused marl-pits to the east of Lea Hall, Harmer Hill, and also at Newton on the Hill and Bilmarsh. At the latter locality it contains a prominent bed of sandstone.

The past year's work has tended to confirm the suggestion made in the 'Summary of Progress for 1915' (p. 9) that the Prees Syncline extends south-westwards to Ruyton and Nesscliff. It is highly probable that the country to the north and east of Baschurch is underlain, not by the Upper Mottled Sandstone, as is indicated on the old map, but by the Keuper Marl. The Keuper escarpment at Middle terminates very abruptly to the north, suggesting a faulted boundary, probably on the line of the powerful north-east and south-west fault well seen to the immediate north of Great Ness. The general effect is to bring the Upper Mottled Sandstone on the south-east against the supposed

Digitized by Google

Keuper Marl on the north-west at Prescott, Fenemere, and Middle. The presence of abundant fragments of Keuper skerry sandstone in the drifts of the whole district to the south of Baschurch and Middle tends to confirm this view.

Around Pim Hill and Harmer Hill the structure is complicated by powerful north-and-south faults. One of these faults, which runs immediately east of Pim Hill, carries notable quantities of green copper ore, which was last worked about 50 years ago.

Farther east, the district of Clive, Grinshill, Lee Brockhurst and Hawkstone has been mapped by Mr. Pocock, who finds that all three divisions of the Bunter are present.

The soft, bright red and brown sandstones that form the upper part of the Lower Mottled Sandstone are exposed at Harcourt Park and Rock Hall, near Preston Brockhurst, where they are strongly current-bedded, and are cemented in places by barytes. At one horizon the sandstone is composed of well-rounded millet-seed grains.

The Pebble Beds form the high ground of Besford Wood, Booley, and Stanton, and have been quarried in places, on a small scale, for building-stone. Their base is marked by a bed of calcareous sandstone and conglomerate, which can be seen in the south bank of the Roden east of Lee Bridge, in the lane between Besford and Lee Bridge, and near Harcourt Park. Outliers of the Pebble Beds have been detected at Acton Reynald and Blaze Coppice, near Preston Brockhurst.

The Upper Mottled Sandstone is exposed on the southern slope of Grinshill, and forms most of the high ground at Weston Heath and Bury Walls (north-east of Lee Brockhurst) that was formerly mapped as Keuper Sandstone. No evidence has been found for the east-and-west fault shown on the map as running through Weston.

The upper limit of the Bunter is not well defined, but the line has been drawn to include all the red, fine-grained sandstones within the Upper Mottled division.

The succeeding Keuper Basement Beds consist of fine-grained yellowish to white sandstones, which have been extensively worked for many years at Grinshill as the well-known Grinshill building stone. The quarries show in places a vertical face nearly 100 ft. in height. Quarrying-operations have now ceased on account of the high cost of labour and the great thickness of marl and 'flag-rock' that has to be removed before the building stone is reached.

These white sandstones are well developed near the Red Castle and along the Terrace in Hawkstone Park.

The Waterstones are yellow, brown, and grey flaggy sandstones, evenly bedded, and for the most part of fine grain. They average 20 ft. in thickness at Grinshill, where they are known as the 'flag-rock,' and are used for rough walling and flags; at one time they were employed for roofing also.

Digitized by Google

At the base of the 'flag-rock' there is a well-marked bed, averaging 9 in. in thickness, of yellowish sand with black specks of manganese, which is known as 'esk' or 'hess,' a local name for ashes. This bed has been found to persist throughout the area surveyed.

Good sections of the Waterstones and esk-bed are exposed near the obelisk in Hawkstone Park, and also near Marchamley.

The Keuper Marl is of the usual red and grey shaly type, with thin sandstones. The feature separating the outcrop of the Marl from the drift-covered area to the north-west, which was mentioned in the 'Summary of Progress for 1919' (p. 9), has been found to continue north-eastwards towards the Abbey.

The principal fault of the district runs north-eastward through Preston Brockhurst and Lee Brockhurst, throwing down the Keuper Marl on the north-west against the Bunter Sandstones on the south-east, as can be well seen just north of Bridleway Gate Farm near Lee Brockhurst, and at Wixhill near Weston.

Copper ores were formerly worked along approximately north-and-south faults close to Clive Church at Grinshill, also at Yorton Bank, and at Wixhill Hill near Weston.

IGNEOUS INTRUSIONS.

Grinshill and Acton Reynald Dykes.—An igneous dyke, usually only 18 in. in width, has been traced by Mr. Pocock for a distance of two miles from near Holbrook, 2½ miles south of Wem, to the Grinshill Quarries above Acton Reynald. Where it invades the Keuper Sandstone it appears to have ascended along several more or less vertical joints, as four distinct branches have been detected in the hill-side. The dyke is seen again crossing the Upper Mottled Sandstone of the Bunter in a direction 80° east of south in an old lane that leads from the Grinshill road to the quarries. One or other of these branches is probably continuous with one of the dykes at Acton Reynald discovered in 1834 by Murchison,[1] whose observations have been confirmed by information obtained that a dyke passes under the house and tennis-court in a north-westerly direction and forms the side of a well, now built over, in the courtyard. Specimens from this locality have been secured. Murchison mentions another parallel dyke, and also a third, crossing these in an east-north-eastward direction, but no information could be obtained about the two latter.

The rock has been provisionally determined by Dr. H. H. Thomas as an albitised porphyritic basalt, though fresh specimens have since been obtained that may modify this determination.

Dr. Thomas reports that so far as he is aware this dyke is quite unlike any of the others that have been proved to be, or may be, of post-Triassic date.

[1] 'Silurian System,' 1839, p. 295.

Digitized by Google

GLACIAL AND RECENT DEPOSITS.

In the Liverpool District mapped by Mr. Wray, numerous borings made in recent years have shown the thickness of the drift to be very variable. Glacial deposits attain their widest development in the south-eastern half of the city.

Along the Mersey shores the boulder-clay forms cliffs 30 ft. high, extending from the Dingle to Otterspool, where it seems to mask a north-and-south hollow in the Triassic rocks.

The Shirdley Hill Sand forms isolated patches preserved in hollows in the boulder-clay. In the neighbourhood of West Derby, where its occurrence has not, it seems, been previously noticed, it attains in places a thickness of over 15 ft. The largest patch occurs around Prince's Park and Otterspool, where it has been dug in comparatively recent times, while it also forms a capping to the adjacent boulder-clay cliffs.

In the south-western part of the Wem Sheet and adjacent margin of the Shrewsbury Sheet, Mr. Wray finds that the Glacial drifts consist of reddish, loamy boulder-clay, with broad spreads of well-bedded gravel and red sand around Stanwardine in the Fields, Baschurch, Broomfields and Montford Bridge. Their thicknesses are extremely variable. Wells and borings have shown them to be 50 ft. thick at Bomere Heath, 100 ft. at Leaton, 96 ft. at Dunn's Heath, and 82 ft. at the Barracks, in the western outskirts of Shrewsbury.

The boulder-clay and the associated gravels consist mainly of slaty Welsh detritus, though granites, apparently of northern origin, and Keuper 'skerry' sandstone, are almost invariably present throughout the district.

Northern erratics appear to be relatively more abundant in the eastern parts of the district. At Leaton, Bicton, Shrewsbury and Preston Montford, the main drift with far-travelled erratics seems to overlie a drift of purely local origin, made up almost entirely of red Triassic sandstone debris.

Shell-fragments are never abundant in the drift, though they have been recorded by Darwin at Shelton Rough, to the immediate west of Shrewsbury, and by Miss Eyton[1] from the now overgrown and disused pits at Merrington Green and Old Wood.

From Ford on the west to Shrewsbury on the east the Severn follows a very meandering course, its total length being nearly 14 miles, while the two localities are only five miles apart. At Ford, in the bed of the river, under a steep bank of boulder-clay, reefs of Lower Mottled Sandstone appear.

The alluvium of the river calls for little comment. It is formed exclusively from the degradation of the drifts and underlying Triassic sandstones. At Ford, Montford Bridge, the Isle, Cross Green, Berwick Park and Gravel Hill, prominent gravel terraces rise 12 to 15 ft. above the level of the recent alluvium.

[1] C. Eyton, 'On the Pleistocene Deposits of North Shropshire,' *Geol. Mag.*, 1870, p. 106.

Digitized by Google

These terraces mark an earlier stage in the history of the river. That at Gravel Hill, near Shrewsbury, is intimately connected with an old river-meander, nearly three miles long, which can be traced past Hencott and Ditherington into Shrewsbury. It forms a flat-bottomed and very broad valley, which appears to have been the course of the Severn while the terrace was in process of formation. At a later stage the river cut through the low col between Frankwell and Coton Hill and forsook its former channel, which is now occupied by two insignificant brooks, clearly 'misfits' to the present wide valley. The same process, though not quite so far advanced, is to be seen at the 'Isle,' where a narrow neck, only 350 yds. wide, separates the two ends of a wide meander 4½ miles long.

At the Berth near Baschurch, at Fenemere, and at Eyton, the Glacial sands, which give rise to an undulating and characteristic moundy landscape, are associated with extensive peat-flats.

Farther to the north-east, where surveyed by Mr. Pocock, the high ground extending from Middle to Hawkstone appears to have acted as a barrier to the direct flow of Glacial material from the north-west.

Boulder-clay of a somewhat sandy type occupies most of the low ground south of Grinshill and east of Acton Reynald, the Bunter sandstones appearing only in isolated patches. On the higher ground a few small areas of boulder-clay are found, at Shooter's Hill, near Besford Wood, and around Moston; while the same material covers the ground between Rakepark Lodge and Kenstone, between Weston and Hodnet.

A spread of gravel occurs west of Lee Brockhurst, and sand covers a considerable area round Moreton Corbet. Both these deposits may be connected with an early stage of the River Roden.

4. Cumberland, Westmorland and Furness.

Headquarters: Whitehaven, Cumberland.

B. Smith, M.A., District Geologist.
T. Eastwood, A.R.C.S. } Geologists.
J. Maden, M.Sc. }

Mr. Bernard Smith proceeded to Cumberland early in November to report upon a suitable centre for headquarters, which were finally fixed at Whitehaven. The work of establishing the centre and getting into touch with local interests was then taken in hand. Mr. T. Eastwood, detached from the Midland staff, arrived on December 9th with Mr. J. Maden, whose training in field-work, under the former officer, was commenced on ground that will be some of the first to be mapped systematically in 1921.

Various enquiries as to future prospects in the coalfield north of Maryport and in the iron-ore regions, have been dealt with. Prospecting for hæmatite by boring has been carried on

Digitized by Google

extensively during the last few years in the Whitehaven district and as far south as Millom, some of the latest borings being situated at Whitbeck beneath the western shoulder of Black Combe. The search for hæmatite is proceeding in the Vale of Eden also, in an area where abundant fragments of high-grade ore occur in the glacial deposits.

The cores of six borings for iron-ore, three in the Calder Bridge neighbourhood and three near Kirksanton, west of Millom, were examined by Mr. Smith, who discovered grey fossiliferous beds and magnesian limestone in the New Red Series at Kirksanton. More than one boring has been pushed down into fine-grained volcanic rock, riddled with veinlets of calcite, on the assumption that it was Carboniferous Limestone.

Some disturbed and partly-dispersed cores from borings at Hensingham near Whitehaven were examined by Mr. Eastwood.

Detailed records of 14 borings or shaft-sinkings for coal or iron-ore, and abbreviated records of others were obtained. An account of the borings for coal at Bank End and Blue Dial near Maryport, first visited in the early part of the year, and the interesting results obtained, is given in Appendix III., pp. 85–91.

Some of the plans of underground and undersea workings of the Whitehaven Colliery have been transferred to 6-in. Ordnance Sheets.

A series of published 4 miles to 1 in., 1-in. and 6-in. Geological Maps, Vertical and Horizontal Sections, and Survey Memoirs on the district is lodged in the office. These will be available for reference.

Detailed descriptions of the lead and zinc mines of the Lake District, examined by Mr. Eastwood, to form one of the Special Reports on Mineral Resources, are being prepared for publication.

5. Northumberland and Durham.

Headquarters: Newcastle-on-Tyne.

R. G. Carruthers, District Geologist.
C. H. Dinham, B.A.
G. A. Burnett, B.Sc.
F. Marsden, B.Sc.
A. Fowler, M.A., B.Sc., A.I.C. } Geologists.

The new unit allotted to the North-Eastern coalfield began operations towards the close of the year. It was decided that, in the first place, special attention should be paid to the 'Limestone Coals,' as they are the main reserve in this part of England. There is much doubt over the finer points of correlations and structure amongst these rocks, and a revision of the existing maps is certainly called for. Messrs. Burnett and Marsden have begun work in the Scremerston field, south of Berwick, and have completed the preliminary measurements of

Digitized by Google

the typical coast-section, in which they have been assisted by Mr. Fowler.

6. Borings for Oil in Derbyshire and Staffordshire.

The progress at the Petroleum Department's borings for oil in Derbyshire and Staffordshire has been carefully followed; Mr. Bromehead has collected geological information from the seven borings in Derbyshire, Mr. Eastwood from those in Staffordshire; several visits have been paid to the sites and many samples examined in the Survey Office. The following table shows the progress from the beginning of 1920 to the time of going to press, May 1921.

Well.	Depth in January 1920.	Depth in May 1921.	Remarks.
	Ft.	Ft.	
Ridgeway -	2,996	2,996	Abandoned January 1920.
Renishaw -	3,645	4,200	Carboniferous Limestone at 4,100 ft.
Brimington -	2,660	4,040	Carboniferous Limestone at 3,000 ft.
Heath - -	2,955	4,009	Carboniferous Limestone at 3,950 ft.
Hardstoft -	3,112	3,112	No change.
Ironville II -	3,570	4,005	Now abandoned.
Ironville I -	2,580	3,655	Still in Carboniferous Limestone.
Werrington -	1,920	—	Fishing.
Apedale I -	1,350	1,350	Abandoned.
Apedale II -	—	3,450	Started September 1920.

From the economic point of view the results have been disappointing. Hardstoft continues to yield about 1 ton of oil per day by natural flow, but elsewhere only traces of oil have been found. At Heath, the nearest to Hardstoft of the other borings, a few ounces of highly filtered oil were met with at the junction of the Limestone Shales and Carboniferous Limestone at 3,950 ft.; slight indications were also found at Ironville II and Ironville I, notably in the latter at 3,630 ft. This 'show' and that at Heath were torpedoed, but no further yield resulted. The top of the Limestone showed no trace of oil at either Brimington or Renishaw, and there is no reason to modify the remarks on the origin and accumulation of the oil made in the 'Summary of Progress for 1919' (pp. 22, 23).

From the purely geological point of view, it will be seen that all the Derbyshire wells have now reached the Carboniferous Limestone; at Ironville I, 1,600 ft. of that formation has been bored through, without reaching the base. Igneous rocks have been encountered in several of the borings; at Brimington, 850 ft. of lavas, with a few thin intercalations of limestone, have

Digitized by Google

already been proved. As was expected, both the Lower Coal Measures and Millstone Grits show a steady increase in thickness from south to north.

In Staffordshire, Apedale No. II well was started a few yards distant from No. I well, which was abandoned, the horizon being just above the Bullhurst Coal. At November 9, 1920, the depth was 1,060 ft. in Coal Measures, and the rocks penetrated were sandstones, shales and several coals. At about 1,465 ft. red and green ashy material was entered, approximately at the top of the Millstone Grit, and this continued to a depth of 3,450 ft. (March 23, 1921). This great thickness of volcanic strata was not expected in the bore, as no similar rocks are known to occur near this horizon except at Astbury (Staffordshire) and Ashover in Derbyshire, where they are comparatively thin.

(B)—SCOTLAND.

The field-work in the Highlands has been proceeding in two districts :—

1. West Highland District under Mr. E. B. Bailey, M.C., B.A.
2. North Highland District under Mr. M. Macgregor, M.A., B.Sc.

The coalfield revision was carried on in two districts :—

3. In North Ayrshire under Mr. E. B. Bailey, M.C., B.A.
4. Stirlingshire and Clackmannanshire District, and part of Lanarkshire (Douglas Coalfield), under Mr. M. Macgregor, M.A., B.Sc.

1. West Highland District.

E. B. Bailey, M.C., B.A., District Geologist.
E. M. Anderson, M.A., B.Sc.
J. E. Richey, M.C., B.A.I.
G. V. Wilson, B.Sc.
G. A. Burnett, B.Sc.
} Geologists.

The area surveyed lies mainly in Mull and adjacent islands including Staffa and Iona, Sheets 43 and 51 of the 1-in. Map of Scotland. A commencement has also been made in Ardnamurchan, Sheet 52.

PRE-MESOZOIC ROCKS.

Iona.—The presence in Iona of Lewisian Gneiss, with associated marble, and of sediments strongly recalling the Lower Torridonian of Skye has long been known, and their distribution has been roughly indicated by Sir Archibald Geikie in his ' Geological Map of Scotland ' 1892. Mr. E. M. Anderson adds a new locality for the sediments of Torridonian type, for besides forming a strip along the eastern side of the island, they

Digitized by Google

compose Eilean Chalbha and the neighbouring foreshore of the north-western coast.

Undoubted altered sediments within the Archæan complex occur (1) in the neighbourhood of the marble quarry, near the most southerly point of Iona, and (2) to the north of Dun Cul Bhuirg, on the western coast. The quarried marble is an almost vertical band about 20 ft. in thickness, pure white in colour, or white with characteristic greenish streaking. It is associated with other certainly sedimentary material, including a dark graphitic rock, which must be an altered shale.

The sediments to the north of Dun Cul Bhuirg also include bands of marble, one of which has been worked to a very small extent for ornamental purposes, under the name of the 'Silverstone.' It is a pinkish marble, variegated by grains of green serpentinous material, and 'silvery' from the presence of pale-coloured mica, no doubt magnesian. There is also at this locality a broad band of brown biotite-gneiss, very massive and unbanded in its weathered appearance. This passes into a graphite-schist, which is in part pyritous, and is strongly reminiscent of a type found elsewhere in Scottish Archæan sediments.

A period of intrusive activity followed the deposition of these sediments, as is shown by the presence among them of very fine hornblende-schists or epidiorites. They are also cut by coarse unfoliated bands of pegmatite of a type already noted by Mr. Craig in the adjacent island of Soa.[1] As pegmatites are almost entirely absent from the neighbouring sediments of Torridonian facies, their occurrences in the cases just referred to would seem to belong to a late phase of igneous activity of Archæan age, a phase which it is to be noted was later than any period of metamorphism and shearing movements.

Unfoliated pegmatites are everywhere the latest intrusions of the Lewisian complex of Iona, and are by no means confined to areas of undoubted sediments. The basis of the igneous gneiss consists in large part (1) of banded granitic rocks, sometimes containing a certain amount of hornblende in their darker laminæ, and (2) of massive hornblende-gneisses, much coarser in grain than the hornblende-schists already mentioned. The whole formation throughout the island is much veined and irregularly intergrown with epidote. A local concentration of magnetite will be noted on p. 43.

The supposed Torridonian series of the eastern strip in Iona may be roughly divided as follows :—

(2) A younger flaggy group characterised by rapid alternations of more siliceous and more shaly material.

(1) An older group of grits and conglomerates with subordinate shale.

---

[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 79.

Digitized by Google

A coarse conglomerate can be seen at certain points along the old gneiss margin. The commonest constituents are fragments of granitic rocks evidently derived from the gneiss, and of any size up to two or three feet in length. Boulders of hornblendic rock and of quartz are also occasionally present, as, for instance, at the dividing line of the two formations at the most northerly point on the island. The conglomerate is interbedded with and overlain by pebbly grits, in which the small pebbles consist of quartz and felspar, while the matrix, like that of the conglomerate, is dark grey or dark green in colour. Less commonly, the base is more yellowish green, suggesting epidote. The part of this formation next to the gneiss shows signs of rather intense crushing, perhaps because it acted as a zone of weakness during some period of stress. There is, however, so far as has been observed, no definite break or thrust along the margin. It is important to realise that the crushing referred to above does not introduce uncertainty in the interpretation of the conglomerates. A visit to the wave-washed exposures at the Pigeon's Cave on the south coast is enough to settle this point. There conglomerate layers are interbedded with grits and shaly layers, and one notes that the included fragments differ markedly in character from their surrounding matrix. The crushing manifests itself in the disruption of the bedded series, it does not produce anything approaching a crush-conglomerate.

The later portion of the grits is interbedded with bands of shale, some greenish, others dark and probably carbonaceous, while there is a broad band of dark shale intervening between the last of the grits and the succeeding flags.

The sediments of the north-western coast and Eilean Chalbha are somewhat puzzling in character, but may very possibly represent some part of the conglomeratic group (1) of the east.

The puckering and cleavage which have affected the similar rocks of Colonsay and Islay are almost absent in Iona. Apart from the movement near the margin of the gneiss, these sediments show little sign of dynamic metamorphism. Their bedding is, however, everywhere steeply inclined, E.S.E. in the eastern outcrop, and south-east in the north-western.

The Ross of Mull Granite must underlie a considerable part of the Sound of Iona, as since Macculloch's day it has been known that three small islets close to the Iona shore are composed of granite of the Ross type. It is interesting to note that the band of shale between the grits and the flagstone group has a spotted appearance where it comes near these islets, but not elsewhere. This alteration would seem to prove the post-Torridonian age of the granite, which has hitherto been somewhat in doubt. To avoid confusion, it should be added that Macculloch speaks of an 'appearance of transition' into the granite, but was probably misled by the presence of felspar grains in the flagstone series and also among the grits.

Digitized by Google

The unfoliated post-Torridonian intrusions of Iona belong to two classes :—

(1) Basic dykes (apparently basalt and camptonite) run in every azimuth between N. 30° W. and due east and west. Some at least of this group are probably Tertiary, and so do not come under the heading of this section.

(2) The second class includes lamprophyres, which are somewhat irregular but show a marked tendency to follow a series of north and south joint-planes, which dip westwards throughout the island at angles of about 30°. It also includes a group of more acid intrusions, usually pink in colour, and sometimes with basic margins. These occasionally follow the joint-planes referred to, but more often are irregularly rolling with a tendency to horizontality. It is possible that the whole of this class of intrusions are of the same period as a set of mica-traps, granite-porphyries, and porphyrites, found by Messrs. Craig and Bosworth,[1] to cut the Ross of Mull Granite while themselves cut by certain north-westerly dykes. Further evidence of the age of the Ross intrusions will be given presently in the description of Gribun.

Gribun.—Iona has been interpreted by Mr. C. T. Clough[2] as probably a part of the foreland of the Moine Thrust. The thrust itself may be hidden in the Sound of Iona or obliterated by the Ross of Mull Granite; at any rate the well-known gneiss of Erisgeir, Inch Kenneth, and Gribun, with the fuller succession of the Ross, almost certainly belong to the Moine series.

Mr. E. B. Bailey and Mr. G. A. Burnett have found the gneiss just mentioned to be remarkable for its pebbly character. It is a false-bedded arkose-gneiss, retaining much of its sedimentary aspect despite a somewhat high crystallization with a development of garnets in certain micaceous partings.

Two steep sheets of coarse mica-trap have been found by Mr. Bailey on the shore N.W. of Balmeanach traversing the Gribun gneiss and themselves cut off by the unconformable Trias. They dip N.W. and almost certainly belong to the same series as the numerous mica-trap sheets recorded by Mr. Bosworth in 1909 as cutting the Ross of Mull Granite. Thus additional indirect evidence is afforded for Judd's generally accepted view that the Ross Granite is of pre-Mesozoic age.

MESOZOIC ROCKS.

Gribun and Inch Kenneth.—Prof. Judd's classic description supplies the natural datum from which to reckon further advance.

[1] E. H. Cunningham Craig, 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull' (*Mem. Geol. Surv.*), 1911, p. 86.
T. O. Bosworth, 'Summary of Progress for 1909.' (*Mem. Geol. Surv.*), 1910, p. 27.

[2] C. T. Clough in 'The Geology of Colonsay and Oronsay, with part of the Ross of Mull.' (*Mem. Geol. Surv.*), 1911, p. 77.

Digitized by Google

Prof. Judd[1] recognised Poikilitic, Upper Greensand (Cenomanian), and silicified Chalk. Some years later Mr. J. S. Gardner[2] discovered Lower Lias in the much landslipped Wilderness (north and south of Aird na h-Iolaire), and corrected Judd's mistaken impression that Greensand is to be found in Inch Kenneth. In addition, Gardner questioned whether Judd's 'Chalk' was *in situ*, for he thought it all *remanié* in Tertiary deposits, but in this he went too far, as may be seen for instance in Allt na Teangaidh, just below the main road.

The results of last year's work may now be briefly stated. The various groups were mapped by Mr. Bailey, the main exposures were measured by Mr. W. Manson, who collected 750 fossils, and the examination of these has been started by Dr. G. W. Lee.

Judd's Poikilitic—or Trias, as one is justified in calling it—is some 200 ft. thick at Inch Kenneth, where the gneiss floor disappears below the sea, and about 10 ft. thick 2½ miles farther south where gneiss rises 700 ft. in the coastal cliffs of Mull. An unrecorded feature is the abundance of pebbles of red Torridon arkose and fine grained (? Durness) limestone. Some of these far-travelled limestone pebbles are enclosed in an envelope of chert.

For about 2½ miles along its outcrop the Trias is succeeded by definite Rhaetic. The prevalent type is dark sandy limestone, or calcareous sandstone, with rather wavy bedding and no trace of concretionary structure. Lamellibranchs are numerous. The best section is in Allt na Teangaidh near Balmeanach, where about 30 ft. are laid bare. The fossils include *Pteria contorta* [*Avicula*], *Gervillia præcursor*, and *Pecten valoniensis*. This is the second record from Scotland of demonstrable Rhaetic beds—the only occurrence known hitherto is the mass of shale found by Messrs. Peach and Gunn tumbled down the throat of a Tertiary volcano in Arran.

In the Wilderness the Trias is succeeded in a low cliff south of Uamh nan Calman by shales and cement-stones. Although the section suggests continuous deposit there is nothing of the type of the Balmeanach Rhaetic—no fossils could be found, but the facies of the shales and argillaceous limestones is distinctly Liassic. What follows is confused by landslipping, but in small cliffs south of Aird na h-Iolaire the lower part of the Hettangian is very definitely represented, and in associated loose blocks one finds a Sinemurian fauna. Taken together these correspond with the Broadford Beds of Skye.

---

[1] J. W. Judd, 'The Secondary Rocks of Scotland.' *Quart. Journ. Geol. Soc.*, vol. xxxiv, 1878, pp. 694, 732. See also a critical discussion of the unconformity at the base of the Gribun Secondaries, J. Macculloch, 'Western Islands of Scotland,' vol. i, 1819, p. 563.

[2] J. S. Gardner, 'Leaf Beds and Gravels of Ardtun, Carsaig, etc. in Mull.' *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 284.

Digitized by Google

The Hettangian of the cliff section is divisible into two :—

(*a*) One ft. red mudstone, overlain by 19 ft. mostly micaceous calcareous sandstone, 8 ft. sandy limestone and calcareous shale crowded with *Ostrea liassica*, overlain by

(*b*) Twenty ft. shales and limestone assignable to the Planorbis Zone.

The Oyster Bed facies, characterising the upper part of (*a*), is well known in the lower Hettangian of England and again in Skye, but not elsewhere in Mull. The *planorbis* fauna of the lower Hettangian has never hitherto been forthcoming in Scotland, though carefully searched for.

The Sinemurian fauna has been found, as already stated, in loose blocks. One may mention *Lima gigantea* indicating the lower part of the Sinemurian, and typical *Gryphaea arcuata*, also betokening Sinemurian but not necessarily its lower stages.

Prof. Judd, the original discoverer of Cretaceous rocks in Scotland, emphasized the bearing of his observations upon Suess's generalisation regarding the Upper Cretaceous transgression of the European area (*op. cit.*, p. 683). For instance, in the Gribun peninsula nothing remains between the Lower Lias and the Cenomanian.

Dr. G. W. Lee, some years ago, justified Judd's employment of the name Cenomanian for the Greensand of Mull by finding a zonal ammonite near Loch Don. The best Gribun exposure is below the road in a great landslip N.E. of Balmeanach. Oyster banks with *Exogyra conica* and occasional *Serpula* are very conspicuous. Additional fossils to those recorded by Judd are : *Pecten orbicularis* and *Pecten asper* (?). Judd's *Spongia paradoxica* is probably based on highly characteristic sandcasts, and Mr. Bailey points out that these resemble forms common in the Upper Greensand of Eastbourne for which Mr. Clement Reid[1] has offered a very different interpretation.

The Greensand of Gribun may be taken as about 20 ft. thick. Above follow white sandstone 10 ft. and Chalk 10 ft. The white sandstone has not previously been described from Gribun, but it is in keeping with Judd's general sequence.

Ardnamurchan.—Mr. J. E. Richey commenced the examination of the Ardnamurchan Secondaries. In the cliff west of Sron Bheag, the southernmost point west of Kilchoan, there is a mass of baked sedimentary rock which is probably Inferior Oolite. It is about fifty feet thick and has a distinct resemblance to Chalk; the exposure is rather inaccessible and has not yet been fully examined.

TERTIARY SEDIMENTS IN MULL.

Mr. Bailey has found that the silicified chalk of Gribun is veined by sandstone, and that in places (*e.g.*, Allt na Teangaidh) similar sandstone constitutes a thin overlying bed. This sandstone shows marked wind-rounding of its grains, and may, there-

[1] Clement Reid, 'The Geology of Eastbourne.' (*Mem. Geol. Surv.*), 1898, p. 5.

Digitized by Google

fore, be claimed as a desert deposit. Another interesting point is that the silicification of the chalk is of later date than the desert sand. An extension of the chert which replaces the chalk in many cases serves as matrix to the grains of sand. Elsewhere it is commonly found that the grains have added fresh crystal facets, and thus lost much of their rounded outline.

To investigate the extent of this Tertiary desert sand, a visit was made to the Tertiary sandstone of Carsaig. Wind-rounding was here again very evident, and included fragments of silicified chalk were seen surrounded by a halo of chert serving as a local matrix for the adjacent sand-grains.

In Allt na Teangaidh the desert sand is overlain by the thin, red mudstone so often met with at the base of the Mull lavas. This deposit, and the somewhat later leaf-beds and coal-seams, obviously indicate a change of climate.

TERTIARY LAVAS.

Local discordance, Bloody Bay, Tobermory.—A general feature of the Mull lavas is the even way in which they follow a thin layer of Tertiary sediments which in turn rests with misleading conformity on underlying Mesozoic rocks. Mr. G. V. Wilson has found a most unusual appearance presented in an old sandstone quarry in the sea cliff of Bloody Bay. The locality is about 1¼ miles S.E. of Ardmore Farm and of easy access from above, or by boat from Tobermory. Prof. Judd, speaking of the sandstone, justly remarks: "the eroded surfaces of these beds is seen to be directly covered by the . . . basaltic lavas" (*op. cit.*, p. 715). The most interesting feature of the exposure is the peculiar way in which the flat-bedded sandstone juts up as a knob into the overlying lavas (Fig. 1). Along

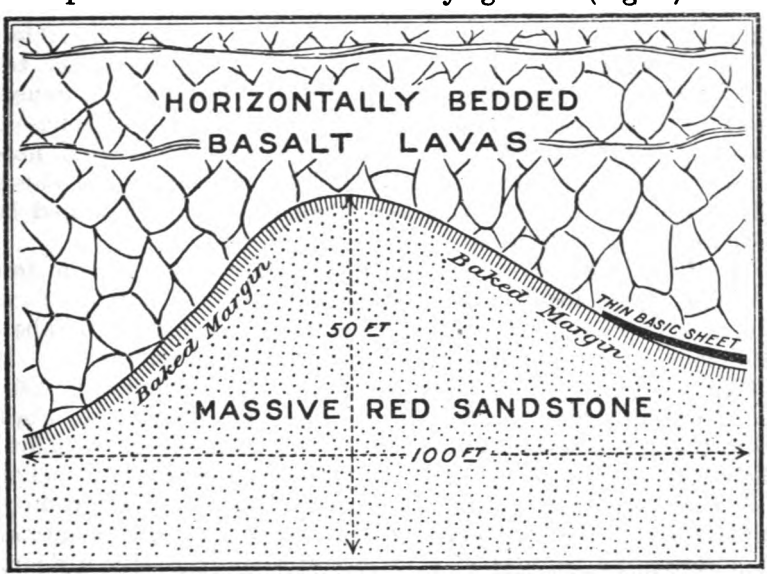

FIG. 1.—Tertiary lavas overlying a weathered knob of sandstone at Bloody Bay.

Digitized by Google

the line of contact the sandstone shows a baked zone which extends inwards for several inches.

The sandstone is of good quality and has been used in the wall of the path leading to Rudha nan Gall Lighthouse. It is at least 50 ft. thick, current-bedded and red in colour, with a small proportion of rounded grains. It also carries irregular concretionary bands of iron-ore. The outcrop can be traced for about 200 yds. and is terminated in both directions by what appears to be a fault running almost parallel with the cliffs and bringing basalt lavas down to sea-level. The age of the sandstone remains doubtful.

Columnar Lavas, Staffa and elsewhere.—The cliffs of Gribun have enabled Mr. Bailey to realise that the columnar lavas there seen all occupy a very low position in the Plateau Lava group of Mull. Comparison with other districts is rendered somewhat unsatisfactory, as columnar structure is often poorly displayed in ordinary inland exposures, but it seems certain that all the columnar lavas of Mull are of relatively early date. They have a geographical as well as a time limit. They reach their fullest development where mapped by Mr. Anderson in the cliffs west of Carsaig, whence they continue by Ardtun into the Gribun peninsula, Ulva and Staffa. Reidh Eilean, outside Iona, has yielded Mr. Anderson a hitherto unrecorded occurrence of columnar structure of spectacular type, but the columnar rock in this case is of unusually doleritic texture, and its field relations are hidden by the sea. The only columnar lava not falling within the south-west corner of the Mull district is an example noted by Mr. Wilson towards the base of the series at Bloody Bay, near Tobermory.

A feature of a large proportion of the columnar lavas of the Mull area is their triple-zoned appearance. They often have a thick slaggy top merging down into an equally thick zone of narrow wavy columns, which rests in turn upon a zone of more massive vertical columns. This combination of zones has received little attention in previous writings, but was noted some years ago by Mr. Anderson and Mr. Wilson in the Carsaig cliffs. It is nowhere better seen than in Staffa, examined last year by Mr. G. A. Burnett.

Prof. Iddings gives a very useful discussion of the zonal jointing of analogous American examples, and attributes the upper zone of columns to irregular rapid cooling from above, and the lower zone to regular slow-cooling from below. His interpretation accounts for a very striking phenomenon visible on the foreshore a little north of the Clamshell Cave, Staffa. Here the two systems of joints, instead of becoming confluent at their contact, as is often the case, seem to be mutually repellant, for they suddenly swing into parallelism. Prof. Iddings'[1] explanation is that the jointing tends to be propagated normally to a retreating isothermal surface corresponding with a definite

[1] J. P. Iddings, 'Igneous Rocks,' vol. i, 1909, figs. 13, 15, 16, p. 322.

Digitized by Google

temperature, and that when cooling from above and below brings two such surfaces together the form of the combined surfaces is materially modified by a rounding off of the angle of contact—from which follows a corresponding deflection of the developing joint-planes. On the other hand, the commonly observed confluence of the two sets of joints is, of course, to be interpreted as evidence of the influence which two approaching joint systems may exercise upon one another, and is not to be taken as a contradiction of Prof. Iddings' explanation.

The two columnar zones of the Fingal's Cave lava of Staffa are among the most familiar of geological phenomena, though they have been previously ascribed to independent flows in Sir A. Geikie's descriptions. Mr. Burnett has shown their true relationship. He has also found that the northern half of the traverse between Clamshell Cave and Goat Cave affords an excellent coast section of the top zone of the Fingal's Cave lava consisting of commingled slag and solid, merging finally to pure slag. In the mixed part of this uppermost zone early masses of slag have clearly been involved in, and carried forward by, still liquid portions of the flow, the latter now represented by columnar basalt. At Goat Cave the slaggy top of the Fingal's Cave lava is covered by a few feet of carbonaceous and ashy sediment, which in turn is overlain by further basaltic flows constituting Meall an Fulann.

It has long been known that the Fingal's Cave lava is underlain by red ash. A convenient exposure can be reached from above at Port an Fhasgaidh. The massive columns here reach down to about a foot from the ash, but the bottom layer of the lava is brecciated and vesicular. A 1-ft. sill of basalt, chilled at top and bottom and clearly transgressive, lies just a little below the lava base.

The Fossil Tree of Burgh.—Another famous columnar lava of the district is that which flowed round and over the fossil tree of Burgh—to use a now familiar name. The cast of this tree trunk stands in a recess of the coastal cliff of the Gribun peninsula, 150 yds. north of the waterfall of Allt Airidh nan Caisteal. Geologically speaking it is the most wonderful spectacle in all Mull, and like so much else of interest in the west of Scotland, was made known over 100 years ago by Macculloch. Sir Archibald Geikie has published a photograph in his Text Book of Geology (1903, p. 758). The cast of the tree is seen in vertical section, and looks like a pipe, nearly 5 ft. broad and about 40 ft. high, and largely filled with breccia consisting of lumps of 'white trap' and charred wood. The lower part of the pipe encloses a partially silicified semi-cylinder of wood glittering with quartz crystals. The diameter of the cylinder is about 3 ft., and outside is a hollow where soft black coniferous wood, a couple of inches thick, may be dug out with a hammer. In Macculloch's day the wood continued as a coat around the silicified cylinder, but since then has been ruthlessly stripped away by curio-hunters.

Digitized by Google

The pipe rises in the heart of a columnar basalt, and the columns as they approach it turn so as to meet it everywhere at right angles. Geikie and Gardner have described the pipe as reaching right up through one lava and overlain by another, but such is not the case. Macculloch seems to have thought that the tree had somehow found its way into a fissure of the basalt.

A prostrate tree is included in a brecciated portion of the same lava exposed in a cave 230 yds. north of the upstanding tree. It is probable, Mr. Bailey says, that these two trees are mere remnants of a forest. At any rate the lower part of the lava in this neighbourhood has very unusual characteristics. It rests regularly on a thin carbonaceous layer following an important ash, but within itself it is wonderfully irregular. It consists, in fact, of a chaotic assemblage of columnar and more or less brecciated vesicular basalt. The columnar basalt traverses the brecciated, or sweeps round great masses of it 40 or 50 ft. high. Everywhere the columns are at right angles to the line of contact, no doubt because the slaggy breccia could offer practically no resistance to contractional force during cooling. The columnar basalt sometimes comes in contact with the underlying carbonaceous mud, and is distinctly chilled, as has been found to be the case with a few other lava bases in Mull; but it is unchilled where it joins the breccia.

The lava is unusually thick, and the irregularity of its basal part may be looked upon as a special feature. Apart from this it exhibits the triple zoning already mentioned as characteristic of the Fingal's Cave lava, etc.

Flow-Banding and Pipe Amygdales.—A curious type of flow-banded lava has been met with in many parts of the district surveyed last year, more particularly in Gometra mapped by Mr. Burnett; the banding is often sufficiently lenticular to remind one of pillow structure, but the lenticles are, on the whole, much too elongated to be called pillows, and they are not defined by noticeably chilled margins. Each band has typically three layers, a basal zone with pipe-amygdales, a middle solid zone, an upper zone with crowded little rounded amygdales. There is a distinct separation of the bands, for nowhere can one point to round vesicles of the top of one band extending up among the pipes of the next. Mr. Richey has found a section at the roadside 350 yds. E. of Kilninian Church, which throws considerable light upon the conditions attending the formation of this banding. Reddening such as is commonly attributed to surface weathering during the volcanic period, extends along the junction lines of the successive bands; this seems to point conclusively to an imperfect contact of the bands, so that it is fair to regard the banding as a surface phenomenon resulting from successive overflows upon the surface of a parent lava.

Pegmatitic Veins.—Several examples of contemporaneous pegmatitic linings to vesicles, and of associated veins, have been encountered this year in basaltic lava flows. Mr. Bailey had

Digitized by Google

previously noted the phenomenon on the shores of the sound of Mull, and Dr. McLintock[1] has described it from the Ben More district. The interest of the recent finds is their occurrence outside the area of pneumatolysis of central and eastern Mull. The pegmatitic veins, where, for instance, they have been found by Mr. Burnett in Gometra, are seen stringing basalt lavas which still carry their olivine in large measure unaltered.

Ben More Mugearite.—Sir A. Geikie,[2] in separating a pale group of Mull lavas forming the upper portion of Ben More, spoke of the occurrence among them of trachytic flows. During the survey of the district it was thought that Geikie's trachytic flows were really a great mugearite sill, and this statement has been published. On the other hand, Mr. Wilson, in the Loch Buie district, definitely recognised as lavas certain mugearites which evidently occupied much the same stratigraphical position as the mugearite of Ben More. Accordingly, Mr. Bailey investigated the matter last season, and states that the continuation of the Ben More mugearite south of Kinlochscridain can be shown to be a lava with a weathered, slaggy top. In keeping with this, Mr. Richey has found a thin sedimentary layer, immediately above the mugearite in Ben More itself, containing numerous fragments of mugearitic type. Moreover, the section which led to the view that the mugearite was intrusive, when examined this year by Mr. Bailey and Mr. Anderson, proved to be misleading.

TERTIARY INTRUSIONS.

Mull Sills.—Messrs. Bailey and Anderson have completed the mapping of the Loch Scridain area of sill-intrusion, and Mr. Wilson has found and mapped a distinct area in the northern end of the island. In both cases the sills are very transgressive.

Among the noteworthy features of the Loch Scridain sills are :—

(1) frequent residuum of pitchstone,
(2) numberless highly altered xenoliths,
(3) occasional and local absence of chilled margins.

(1) and (2) of the above have often been described already. Mr. Bailey has now found instances combining all three characteristics, as, for instance, at Scobull Point, Loch Scridain. Messrs. Anderson and Radley[3] have pointed to the pitchstone residuum as evidence of retarded crystallization, and have argued that it has been determined by an unusually high water-content in the magma supplying the sills. Mr. Bailey points

[1] W. F. P. McLintock, 'On the Zeolites and Associated Minerals from the Tertiary lavas around Ben More, Mull.' *Trans. Roy. Soc. Edin.*, vol. li, 1917, pp. 15, 18, 21.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, p. 214.

[3] E. M. Anderson and E. G. Radley, 'The Pitchstones of Mull and their Genesis.' *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, p. 205.

Digitized by Google

out that the characteristics (2) and (3) suggest retarded consolidation in contact with cold surfaces, not by any means the same phenomenon as retarded crystallization, but very likely attributable to the same cause.

Mull Dykes.—The belt of N.W. dykes belonging to Mull is about 10 miles broad. Mr. Wilson has found that the topography of northern Mull, within the belt, is lineated N.W. and S.E., in striking contrast to that of adjacent districts.

Ardnamurchan Complex.—In a preliminary investigation of the Ardnamurchan peninsula, Mr. Richey has confirmed Dr. Harker's[1] announcement of a well-defined belt of centrally inclined basic sheets (cone-sheets). The sheets dip to a common centre, which is situated approximately beneath Beinn na h-Imeilte, between Sanna Bay and Kilchoan. The belt can be traced round half the circumference of a circle, extending from Faskadale on the north side of the peninsula to the south-west side of An Acairseid. It is at any rate three miles in annular width. The sheets composing the outer half of the belt are individually the more massive, and attain unique development on Ben Hiant,[2] where single members are upwards of 100 ft. thick. The dip also varies, becoming gentler towards the exterior of the belt, as, for example, in the Ben Hiant district.

The great gabbro mass, long known to form the western part of the peninsula, has a steep or vertical junction, which follows closely the strike of the belt of cone-sheets. It is considered to be later than the sheets for the following reasons :—

(1) The gabbro is free from the sheets, whereas the sheets occur in great force immediately outside it.

(2) The sheets, together with their country rock, become increasingly altered by thermal metamorphism towards the gabbro junction.

(3) An isolated area of basalt lava traversed by sheets, presumably belonging to the set of cone-sheets, was observed surrounded by gabbro on Meall an Tarmachain.

PREGLACIAL MARINE EROSION.

The district includes many evidences of Preglacial marine erosion at about 100 ft. above sea level, already described by Mr. Wright,[3] whose conclusions have been confirmed. Of cognate interest is an old sea cave at a higher level, to which Mr. Burnett's attention was directed by Mrs. Clark of Ulva. It opens on the south-east slope of A'Chrannag, Ulva, and its floor, where reached in a trench, lay 150 ft. above high-water mark. It measures

[1] A. Harker, 'Anniversary Address of the President.' *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1917, part 1, p. xciv.

[2] A. Geikie, 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, pp. 318–322.

[3] W. B. Wright, 'Preglacial Shoreline in the Western Isles of Scotland.' *Geol. Mag.*, 1911, p. 97.

Digitized by Google

40 ft. broad, 50 ft. deep, 25 ft. high, and its bottom is covered with a deposit of boulder-clay up to 5 ft. thick, charged with granite, gneiss, and Liassic limestone derived from Morvern and the Sound of Mull. The far-travelled erratics are, taken together, much more numerous than basalts such as might have come from the island itself. The level corresponds with that of a well-marked, though heavily glaciated, shoreline found some years ago by Mr. Anderson at the head of Loch Scridain.

ECONOMICS.

Iron Ore, Iona.—Magnetic iron ore was known to have been found near the southern end of Iona. Mr. E. M. Anderson reports its occurrence at two localities :—

(*a*) Close to the shore directly north of the eastern end of Eilean Musimul. The material here forms a vertical band from 2 ft. to 4 ft. in width, traceable for about 200 ft., and running parallel to the banding of the adjoining gneiss. The magnetite is mixed with garnet and other impurities, but the state of concentration is, perhaps, rather greater than that of the next locality.

(*b*) Close to the shore just west of Port an Fhir-bhreige (the western part of St. Columba's Bay). There is here a zone of impregnation some 10 or 15 yards in width, which can be traced for nearly 100 yards; but the deposit is most irregular, and only a small part of this thickness can be classed as even inferior ore.

Until assays of the material have been made, it is not possible to estimate the amount of iron, and it is likely that the limited nature of the deposits so far apparent would prevent them from being profitably workable.

Marble, Iona.—The well-known Iona marble quarry has not resumed working since the war. The stone was used for interior decoration, especially in churches. The available reserves are not sufficient to allow the development of the industry on a large scale, but would probably meet a limited demand for many years to come.

Sandstone, Bloody Bay, Mull.—Attention may be directed to the sandstone of Bloody Bay, described on p. 38. It has already been quarried for the Rudha nan Gall lighthouse, and is a serviceable stone on the water's brink should building material be again required in this locality.

Lime, Mull.—The white sands of Calgary Bay could supply an inexhaustible supply of lime. Mr. Wilson reports rather more than 70 per cent. of $CaCO_3$ in a type sample.

The cornstones at the entrance of Loch na Keal might perhaps be used for local purposes. The most favourable outcrop is that of the sea-cliff below Inch Kenneth Chapel.

Digitized by Google

2. North Highland District.

M. Macgregor, M.A., B.Sc., District Geologist.
C. H. Dinham, B.A.
H. H. Read, B.Sc., A.R.C.S. } Geologists.
D. Haldane

Field-work was resumed during the past season in the North Highland District, and considerable progress made with the survey of One-inch Sheet 102. The ground surveyed lies in the south-eastern quarter of the sheet, partly in Sutherland, partly in Easter Ross.

EASTER ROSS.

In the Ross-shire ground, Mr. Dinham surveyed an area lying north of the lower part of Strath Carron. The greater part of this tract is covered by morainic drift, and the rocks, which are found only in the stream sections and along the shores of the Kyle of Sutherland, consist of the usual siliceous granulites of Moine type, with thin and rare pelitic bands, scarce sills of chloritic and garnetiferous hornblende-schist, and lamprophyres of two types, distinguished by brown and brick-red weathering. Near Culrain, where the Kyle first narrows, the top of Lamentation Hill (Creag a' Choineachan) and the ground to the west of it are comparatively free from drift. At the very summit of this hill outcrops a brown-weathering lamprophyre, with abundant well-rounded inclusions of schist and of a pink granite. The contrast between the resistance of this tough, scarcely jointed rock to the action of ice, indicated by its tendency to occur in rock knobs, and its easy susceptibility to ordinary atmospheric weathering, is well illustrated here. This dyke has been traced at intervals for at least 1,000 yds. to the W.N.W.; in the opposite direction it is probably continuous, though the connection is not visible, with the exactly similar dyke of Sithean Mor across the Kyle (p. 47).

The 50-ft. Raised Beach forms a well-marked flat here and there on the west shore of the Kyle. At the lower end of Strath Carron the sands and gravels of this beach must have constituted a delta, the greater part of which was situated below the level of tidal waters, while the higher layers, and the part which lay furthest upstream, were fresh-water deposits at the mouth of the Carron; similarly with the present-day river, the delta, formed partly at the expense of the earlier one, lies on the average two or three feet above high-water mark, and the tides do not penetrate more than a quarter of a mile upstream from the river mouth, so that the highest layers of the delta are properly fresh-water deposits. The 50-ft. beach rises to 62 ft. about a third of a mile east of the railway, but beyond this point the surface becomes broken and the beach merges into a tract of irregular gravel mounds, separated by hollows without outlet, indicating the proximity of the tongue of a valley glacier.

Digitized by Google

South of the viaduct across the Kyle at Culrain the 50-ft. beach must have been chiefly formed out of materials brought by marginal and other streams, and deposited here at the foot of the Oykell Valley glacier. The fluvioglacial origin is also indicated by the presence of two or three kettle-holes, close to Culrain Station, in the otherwise flat-topped beach. Before the sea sank below the 50-ft. level, the ice had retreated at least as far as Inveran, for the raised beach, though mostly forming a narrow fringe with broader expanses near Inverhouse, still makes a well-defined flat, with a large kettle-hole near the sharp bend of the road east of Rheantaoir. West of this, however, the terrace breaks up into hollows and mounds, the latter not rising higher than the level of the beach until beyond Rhelonie, where all trace of the terrace feature finally disappears.

There is some indication of a glacial overflow channel which, entering the wood south of Rheantaoir just below the 100-ft. contour, utilised and partly deepened the gorge leading eastwards to Inverhouse. The broad spread of 50-ft. beach at this point, already referred to, may be largely formed out of materials brought through this channel into tidal waters, at a time when the ice-foot lay between Inveran and Rheantaoir.

SUTHERLAND.

Messrs. Read and Haldane report that in the ground surveyed by them between the Kyle of Sutherland and Strath Fleet, the country rock consists of siliceous granulites in which occur granite masses and subordinate igneous rocks of various kinds.

Schists.—In type, the Moine rocks are very uniform throughout; they are white or pinkish siliceous granulites, in which what appear to be relics of felspar pebbles are occasionally seen. Narrow bands of a semi-pelitic nature are of rare occurrence. At a few places, lenses and small bosses of dark hornblendic rock have been found. These are usually schistose, but are occasionally rather massive, and are presumably of igneous origin. Throughout its extent, the siliceous granulite is traversed by great numbers of acid stringers, veins, and small dykes, which form intricate complexes. About a mile S.W. of Achany Lodge a prominent knoll, consisting of white vein quartz much crushed and broken, rises out of the surrounding peat flat; a similar smaller knoll occurs some distance to the south-east.

Granites.—In the Migdale area and northwards by Loch a' Ghobhair and Loch an Lagain, Mr. Read has mapped a large mass of granite, which forms the crags of Migdale Rock, Craig a' Bhealaich and Creag a' Ghobhair, and covers an area of about six square miles. It is a non-foliated, fine-grained whitish rock with a small amount of biotite. On Migdale Rock, the granite is traversed by numerous contemporaneous pegmatites of an average width of 1 in. These seem to have been formed by exudation of the last juices of the granite magma into early

Digitized by Google

joint planes in the already solid normal rock. The direction of the joints is N. 10 E—S. 10 W. Later still seem to be narrow quartz veins which run N. 10 W.—S. 10 E.; these later veins have occasionally pegmatite at their margins and quartz at their centres.

On its western and southern margins the Migdale Granite has a sharp junction with the Moine granulites; the granite is welded to the foliation planes of the granulite, which is little altered, possibly because it had already reached so high a degree of mineral stability. On the eastern and northern margin, however, no definite line can be drawn for the junction, for here a thorough complex of granite apophyses and granulite is found, which forms a belt half a mile or so in width outside the solid granite.

At Beinn Donuill, 5 miles N.E. of Bonar Bridge, a basic margin to the granite is seen. In parts the basic mass is composed of a very coarse black hornblende-biotite-rock of a scyelitic nature; with this are associated hornblende-biotite-rocks with patches of pink felspar; other types show approaches to granite. There is here little doubt that the scyelite and associated hybrid rocks belong to the Migdale Granite intrusion. The importance of this fact will be seen immediately in the discussion of the Ach'uaine hybrid rocks.

Part of the Lairg-Rogart Granite falls within the area surveyed. Mr. Haldane notes that in the Fleet valley the rock is an unfoliated coarse-textured biotite-granite, with occasional patches of dark basic material. This granite passes eastwards into the somewhat paler type seen at Dalmore.[1] This intrusion is separated from the Moine granulites by a well-marked belt of crush with a N.W.—S.E. direction which has determined the course of the Fleet valley at Acheille.

Rocks probably of hybrid origin.—At Ach'uaine (Gælic—green field), 2½ miles N.N.E. of Bonar Bridge, the vivid green herbage of the fields makes a striking contrast to the heather-clad ground occupied by the siliceous granulites and Migdale Granite. On examination, Mr. Read finds this to be due to the occurrence of ultrabasic and associated rocks at this locality. These rocks form a series of detached, elongated, irregular masses on the ground around Ach'uaine and Ledsaurich. They have also been met with further north around Cnoc a' Choire Bhuidhe by Mr. Haldane. From Ach'uaine a broken belt runs north for nearly a mile to Asdale. Near Ledsaurich another belt runs for about a mile with an average width of 100 yds.

Until a thorough microscopic examination of these rocks has been made, little beyond the impressions formed in the field can be given. The rocks of these basic masses are regarded as mixed rocks formed from two types, an ultrabasic scyelite type and a granite type resembling the Migdale granite. The

[1] *Vide* 'Summary of Progress for 1909' (*Mem. Geol. Surv.*), 1910, p. 41.

Digitized by Google

scyelite is a hornblende-biotite-rock with large plates of black mica often 2 cms. across; the granite is a pinkish very fine-grained rock with scarce and small biotites. It is considered that, by the mixture of these two types, sometimes as magmas, sometimes by incorporation of ultrabasic in acid magma, sometimes by penetration of almost solid ultrabasic material by acid magma, there have been produced the innumerable varieties of mixed rocks seen in these masses. Some of these mixed types are :—

(1) Hornblende-biotite-rock with large patches of pink felspar.

(2) Finer grained rocks of similar composition to (1).

(3) Streaky rocks formed by inclusion of hornblende-biotite-rock in a granite base.

(4) Purplish 'acidic' types with large plates of biotite.

(5) Innumerable mixtures formed by the intrusion of granite into scyelite without assimilation.

Mr. Dinham has found what appear to be rocks related to those just described at a locality 150 yds. south of the top of Lamentation Hill in Ross-shire.

Lamprophyres.—Mr. Haldane has recorded a lamprophyre dyke on the summit of Sithean Mor, 1 mile east of Invershin. This dyke trends almost due east-and-west and can be traced for over a quarter of a mile, and is possibly the continuation of that noted by Mr. Dinham on Lamentation Hill in Ross-shire (*see* above, p. 44). It cannot be traced far east of Sithean Mor. It is a quite unfoliated dark massive rock with abundant large plates of black mica. It contains many inclusions of Moine granulite and of granite (Migdale Granite?), which stand out as knobs on the weathered surfaces. Similar lamprophyre dykes have been found by Mr. Read at Creagan Reamhar, Garbh Leathad, Allt na Feith Moire and Allt na h' Atha. That these lamprophyres are later than the Migdale Granite has been proved by Mr. Read's discovery of a lamprophyre dyke cutting the granite at Loch Leisgin.

Old Red Sandstone.—At the eastern edge of Sheet 102 and south of Strath Fleet a small faulted-in patch of flaggy red sandstone has been noted by Mr. Haldane. Granite occurs both to the north and to the south of this patch but no actual boundaries are seen. The sandstone dips at 30° to the south-east, and is probably the termination of the Old Red Sandstone belt shown in Sheet 103, which may be here cut out by the large N.W.–S.E. fault already mentioned as occurring in the Fleet valley.

Pleistocene and Recent.—On the north-east shore of the Kyle of Sutherland, between Bonar Bridge and Linsidemore, there is a well-marked 50-ft. beach which, when traced up the Oykell valley, displays features similar to those described above by

Digitized by Google

Mr. Dinham for the beach on the south-west side of the Kyle. There are also traces of a lower shelf at about 25 ft.

Coalfield Revision.

3. North Ayrshire Coalfield.

Field-work was mainly carried on in the volcanic district of Sheet 22. Mr. Anderson was engaged in the completion of coalfield maps commenced by the late Mr. C. T. Clough and himself. A boring for coal was visited near Rankinstone, and replies were furnished to enquiries from colliery managers entailing field observations in the Troon and Dalmellington districts.

The revision of the Calciferous lavas of the Clyde plateau has been continued by Mr. Richey and Mr. Burnett in the hill country between Stewarton and Mearns. Chief interest centres in a great spread of trachytes,[1] of which 8 square miles have now been mapped. It is probable that most of these trachytes are lava flows, though this conclusion is based on somewhat sparse observation of vesicular tops, unchilled margins, and intercalated beds of tuff. The stratigraphy of the area is especially difficult to work out, as the country is of low relief, with scarp-featuring ill developed; added to this there is extensive faulting and also an original discontinuity of the various lava zones, some of which were referred to in last year's 'Summary of Progress.' It can, however, be definitely stated that the widespread top Dalmeny Group of last year's classification continues eastwards through the uplands north of Fenwick, and is underlain by trachytes, to some extent associated with mugearite and various types of basalt, and that this assemblage is in turn underlain by a thick group of macroporphyritic basalt lavas. Considerable areas of trachyte occurring to the east of the Mearns–Fenwick road appear to be overlying the continuation of what is elsewhere the top group of Dalmeny basalts, but their mapping is incomplete. In this connection it may be mentioned that evidence of an acid phase posterior to the Dalmeny Group is afforded in other parts of North Ayrshire by the occurrence of abundant felsitic pebbles in the volcanic detrital beds that form the base of the Calciferous Sandstone sediments overlying the lavas.

4. Stirlingshire and Clackmannanshire.

The revision of the Stirling and Clackmannan area of Carboniferous rocks was continued during the spring and autumn by Messrs. Dinham, Read and Haldane, and that of the Douglas area by Mr. Macgregor. In addition to the normal field work short visits were paid to different localities in connection with

[1] J. E. Richey, 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 27.

Digitized by Google

various 6-in. maps of the Central coalfield in course of publication. Borings for coal and ironstone in the districts of Barrhead, Glasgow, Airth, Bo'ness and Douglas were also examined during the course of the year.

STIRLINGSHIRE.

Mr. Dinham, in continuation of his work on the Lower Limestones on the north side of the Central coalfield,[1] began a re-examination of certain critical sections in the Corrie Burn district in 1-in. Sheet 31. The discovery in the middle burn of a representative of the "sandy encrinital limestone of Campsie," which occurs between the Hurlet and the Blackhall Limestones, is worth recording. This bed had previously been discovered in the Shields and Bannock burns,[2] but had not been recognised at Corrie, which lies between them, doubtless owing to the fact that the limestone is everywhere decalcified and resembles an ochreous sandstone. Its position in the Corrie sequence is shown in the following table :—

	Ft.	in.
Gap	–	–
Sandy LIMESTONE with occasional encrinites, &c.; the bottom 15 in. consists of thin beds very full of various marine fossils. Thickness apparently about	6	–
Gap about	5	–
Faky blaes	1	–
Sandstone, flaggy false-bedded	1	6
Sandstone, thin bedded and colour-striped	2	–
Gap	5	–
HURLET LIMESTONE seen here	7	–

The decalcified limestone is seen again 100 ft. further to S.W., at the east corner of an old quarry in the Hurlet Limestone.

In 1-in. Sheet 39 Mr. Dinham was engaged on the survey of the ground lying south and east of Stirling. The chief points of interest in the surface geology are :—

(i) The discovery at Craig Moss, 3 miles S.E. of the town, of a hitherto unmapped 'islet' of rock in the middle of the Carse flats. (ii) The presence of large erratics of Highland grits of Ben Ledi type, and of Old Red Sandstone conglomerate, on the slopes of Dunmore Hill. (iii) The tracing of the old coast line of the '100-ft.' raised beach. The inner margin of this beach appears to rise to at least 145 ft. above O.D., and is fringed by terraces of sand and gravel which at Cambusbarron attain a thickness of at least 50 ft. Around Carnock and Castleton the old coast line crosses the outcrop of the massive sandstones of the Millstone Grit. These now form conspicuous lines of crags

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, pp. 34-41.
[2] *Ibid.*, p. 38.

Digitized by Google

—a phenomenon rare in the Millstone Grit of Scotland, and due in this instance to the removal of the usual boulder-clay cover by the waves of the old sea, on whose shore they projected as rocky reefs and islands. The sudden disappearance of these crags as the old coast line is followed towards the north-west, coincides with an abrupt passage, across a large fault, from Millstone Grit into strata of the Upper Limestone Group, in which sandstones are neither as thick nor as numerous. This fault has also been approached from the north side in the workings of Carnock Pits; its throw amounts to at least 200 fms., and it is probably a continuation of the big Campsie Fault, which separates the coalfields of South Stirlingshire from the lavas of the Kilsyth Hills.

CLACKMANNANSHIRE.

Coal Measures and Millstone Grit.

Mr. Read has begun the revision of the Alva, Menstrie and Alloa districts of the Clackmannanshire coalfield. A general section of this coalfield is given in one of the published sheets of vertical sections (Sect. 4, Sheet 5, Scotland, 1877). It illustrates the ground immediately adjoining Devon Ironworks (now Devon Colliery) about 1 mile south-east of Alva, and shows at the top 72 ft. of red sandstone assigned to the Barren Red Measures. These beds are seen in the quarries around Devon Colliery, in the railway cutting near Black Row, and probably also in the Silver Glen, 500 yds. east of Alva Church. They are coarse reddish false-bedded sandstones and occupy the centre of the northernmost basin of the Clackmannan field. Their correlation with the Barren Red Measures is still open to doubt since sandstones of very similar type occur in this district within the limits of the Productive Coal Measures.

Abandoned shafts of which no records exist are very common in the Clackmannanshire field, coals and ironstones, both clayband and blackband, having been wrought here from an early period. Some of the workings must be at least 125 years old; the clayband ribs above the Nine-Foot coal, for example, were mined for the long-abandoned Devon Ironworks (*circa* 1792–1856).

The Devon basin is limited on the north by the Ochil Fault. Good sections are seen in the Alva, Silver, Mill and Kirk burns, which drain the face of the Ochils, and these enable the position of the fault to be fixed with some accuracy. In Alva Glen, Lower Old Red volcanic rocks are brought against smashed and upturned red sandstones of Carboniferous age. In the Silver Glen, the red sandstones already mentioned are seen to overlie white sandstone, blaes and fakes with thin coals dipping steeply south off the fault. Between the volcanic rocks and the Carboniferous sediments there is a dolerite intrusion which presents chilled edges to the volcanic rocks, and is crushed on its south side against the Carboniferous. In the Mill Burn, blaes, fakes

Digitized by Google

and sandstone are almost vertical against the fault. A dolerite intrusion is found between the volcanic rocks and the Carboniferous, but here it appears to have chilled margins on both sides. In the Kirk Burn again the dolerite shows a chilled margin against the volcanics while it is smashed and broken along its junction with the sediments. It seems probable, therefore, that there has been repeated movement along the line of the Ochil Fault. It is still a notable line for earthquake tremors.

Along the western side of the basin, at the margin of the 50-ft. terrace on the south side of the River Devon and east of Tullibody Bridge, coarse white friable sandstones occur, which are referable to the Millstone Grit Series. This view is confirmed by the fact that in Tullibody Mine, at the north end of Günther's Wood, the Coalsnaughton Main Coal, lying near the base of the Coal Measures, was formerly wrought at the outcrop. Bores on Knowfaulds and on the ground east of Tullibody show that there also Millstone Grit strata are present at the surface.

Mr. Haldane has extended the revision of the Clackmannanshire coalfield to the Clackmannan and Kincardine-on-Forth districts. Part of the ground is occupied by much faulted strata of Coal Measures age, to the east of which the Millstone Grit forms the higher ground of Tulliallan Forest and Bath Moor. The only stream of importance in this area is the Black Devon and, apart from the numerous partial sections seen along its course, natural rock exposures are few. The Cherry and Splint Coals, with their associated strata, are seen in the Devon 400 yds. west of Mary Bridge to the north-west of Clackmannan, while the Coalsnaughton Main is exposed where the river flows along the north of Birkhill Wood, 2 miles north-east of the same town. The district contains very many old workings, of most of which no records can now be traced. Of the numerous disused sandstone quarries the one at Craigrie, a mile south-west of Clackmannan, is the most interesting, as it furnishes an excellent section of the Nine-Foot Coal. The details of this section are :—

	Ft.	in.
Grey fakes	6	–
Black blaes	–	6
Coal	–	8
Fakes	–	6
Coaly rib	–	1
Fakes with clayband nodules	–	8
Sandstone	–	4
Clayband ironstone	–	1
Sandy fireclay	–	3
Flaggy sandstone and fakes	4	6
Blaes with thin clayband ribs and nodules	1	11
" " " " "mussels"	1	7
Black blaes with fish remains	–	3
Nine-Foot Coal, with 4-in. of parrot on top	9	–
Fakes	1	–
Massive, yellowish-white sandstone - At least	25	–

Digitized by Google

Glacial and Recent.

Outside the limits of the 100-ft. raised beach the ground is covered by a thick mantle of boulder clay containing many boulders derived from the Ochil Hills and from the Highlands to the north-west (*cf.* above, p. 49). Striae observed on the volcanic rocks of the Ochils indicate a south-easterly ice-flow, but the marked east-and-west orientation of the drumlins near Clackmannan shows that there the movement was in conformity with the general movement of the ice through the Central Valley.

Around Alloa the 100-ft. beach is well developed. Its margin has now been traced, generally as a well-marked feature, from Tullibody to Kincardine-on-Forth. Its deposits are mainly sands and clays, and at Hilton Brick Works near Alloa, dark chocolate clay, 30 ft. thick, is being worked for the manufacture of bricks, sanitary ware, &c. Clays of the 100-ft. beach were also formerly wrought to the north of Clackmannan.

The River Devon, below Tillicoultry, meanders through the flat 50-ft. carse lands, composed of a stiff brown clay. Upon the carse well-marked deltaic cones have been formed by streams issuing from the Ochil Hills, and on these the villages are built. Where the Black Devon traverses the deposits of the 50-ft. beach to the south-east of Alloa, small specimens of *Cardium* and of *Mytilus* have been obtained from a shell-bed in some of the blue clays. This beach has been more or less distinctly followed as far as Kincardine.

A deep buried channel runs up the Devon valley between Menstrie and Tillicoultry, as described in Mr. H. M. Cadell's 'Story of the Forth' (Glasgow, 1913, p. 90). A boring at Glenochil Distillery, Menstrie, passed through 337 feet of surface deposits, and did not reach rockhead. The height of the surface at this locality is only 35 or 40 feet above O.D.

LANARKSHIRE.

In the Douglas Coalfield, Mr. Macgregor and Mr. Manson examined and measured a number of sections in the Carboniferous Limestone Series at Bankend. The Poneil Water at this locality, along with its tributary the Hagshaw Burn, furnishes a fairly complete sequence from the Index Limestone to the Ell Coal and from the Macdonald Coal down to the well-known *Productus giganteus* limestone near the top of the Calciferous Sandstone sediments. A large suite of fossils has been collected from the various members of the Lower Limestone Group, but pending detailed examination of this material their correlation is held over.

As a supplement to the short account of the Douglas coalfield given in the 'Summary of Progress for 1919' (pp. 31–4,) the sections of the Limestone Coal Group exposed in the Hagshaw Burn may be shortly summarised. The Index Limestone, formerly exposed near the mouth of the burn, can no longer be examined

Digitized by Google

in situ, but loose rocks that remain resemble the exposure in the old quarry at Longhill Burn some 2 miles to the east. The section of the Smithy and Dross Coals, and of the strata below and above them, is as follows :—

	Ft.	in.
Faky sandstone	3	–
Coal	–	7½
Fireclay	1	–
Blaes	1	6
Parroty blaes	2	–
Coal	–	6
Coaly fireclay	–	6
Faky sandstone with rooty top	9	6
Sandstone and faky sandstone	6	11½
Fakes and faky blaes	2	3
Firm blaes	3	3
Soft dark blaes	1	3
Firm blaes	3	3
Smithy Coal	2	3
Dark fireclay	1	4½
Coal	–	4
'Horn' or Wild Gas Coal	–	6
Dross Coal	3 ft. 4 in to	3	10
Sandy fireclay	8 in to	–	10
White rooty sandstone with irregular ribs of blaes	3	9
Blaes	10 in. to	1	–
Parroty blaes	1	3
Blaes	2	11
Faky sandstone	–	8
Blaes	3	5
Irony 'kingle' (*i.e.*, hard sandstone) lenticular up to	–	6
Blaes	1	6

The details of the section of the Ell Coal are :—

		Ft.	in.
Sandstone roof		–	–
Ell Coal	Head Coal	2	9
	Dark fireclay	1	6
	Coal	1	–
	'Horn' or Wild Gas Coal	–	11
	Coal	1	7
White rooty ganister-like sandstone floor.			

No exposures of the Nine-Foot or Six-Foot Coals occur in the Hagshaw Burn, but it should be noted that there is a narrow troubled area to the south of the fault which cuts off the coals noted above at a point about 450 yds. from the junction with the Poneil Water. It is not yet certain in what part of the sequence these troubled beds lie. They are followed up-stream by a very

Digitized by Google

fine exposure of the Macdonald Coal. The details of the section are :—

	Ft.	in.
Dark blaes with clayband nodules and ribs; *Lingula* predominant, some brachiopods	–	–
Clayband rib — 2½ in to	–	4
Dark shelly blaes, with brachiopods, &c.	1	6
Layer of flattened shelly nodules of irony limestone	–	2
Dark shelly blaes	2	9½
Dark blaes, very shelly	1	9
Limestone rib	–	7
Dark blaes, very shelly	1	8
Macdonald Coal — Coal	2	–
Macdonald Coal — Dark Fireclay	–	4
Macdonald Coal — Coal	2	10
Fireclay and balls	3	2
Dark parroty blaes with *Lingula*	1	–
Faky sandstone — 1½ ft. to	3	–
Blaes and hard fake ribs	8	6
Fakes, faky sandstone and blaes — at least	13	6½

There is a break in the sequence here but the Top Macdonald Limestone is not far below the base of the section just quoted. The marine beds overlying the Macdonald Coal, and the Lingula band which occurs a few feet below it, are very useful horizons in identifying the seam in the workings. Another exposure of the Macdonald Coal is seen in the Poneil Water nearly five-sixths of a mile east of the ford at Brockley; here it shows :—

	Ft.	in.
Shelly blaes (several feet thick)	–	–
Coal	1	6
Fireclay	1	0
Coal	–	7
Fireclay	–	8
Coal	–	7½
Fireclay	3	6

The attenuation of the seam in an easterly direction is also a characteristic of all the higher coals; on the eastern margin of the Douglas-Ponfeigh coalfield, however, they appear in still thicker development.[1]

The Macdonald Limestones are exposed at several localities and from the blaes associated with the highest of these *Posidonomya corrugata* has been obtained. The Hawthorn or Main Limestone is also seen at various places in the Poneil Water and Hagshaw Burn, and shows 6 or 7 fathoms of very fossiliferous nodular limestones and limy fakes, containing *Lithostrotion* bands, large *Producti* and corals. A 6-in. or 7-in. coal underlies it, while above it are 4½ ft. of faky sandstone and 2 ft. of a very white ganister-like sandstone with a nodular top. This sandstone

[1] 'Summary of Progress for 1919' (*Mem. Geol. Surv.*), 1920, p. 33.

Digitized by Google

forms an exceedingly useful index in working out the details of the various partial sections. On top of it occurs a lenticular sandy ironstone, apparently worked in former days. This band reaches a thickness of 8 in. but is often absent; above it comes a slaty pyritous rib about ½ in. thick containing fish remains, and forming the base of a thick series of dark crumbling fossiliferous blaes.

5. Borings for Oil at D'Arcy and West Calder.

Periodical visits to the experimental borings for oil have been continued and the samples of sediments and pieces of rock have been examined by Mr. Tait.

D'Arcy Oil Well (1-in. Sheet 32 Scotland, 6-in. Sheet, Edinburgh, VIII., S.E.).—This boring, situated about 1 mile S.S.W. of the mining village of Chesterhill (3 miles S.E. of Dalkeith) commences in the Lower Limestone Group where it rises in a clearly defined anticline that forms a local fold along the general anticlinal uplift between the Roman Camp and Cousland on the eastern side of the Midlothian Coal Basin. South of the boring the anticline is crossed by a fault and several others have been proved in colliery workings both to the east and west of the local anticline.

The boring commences a few feet below the outcrop of the D'Arcy Limestone (No. 2 or Skateraw Limestone), the outcrop workings forming a semicircle round the site of the boring. At a depth of 27 fathoms it passes through limestone beds containing marine shells interbedded with sandstones and then continues in an alternating series of shales, sandstones, fireclays and marls to a depth of 117 fathoms. At 118 fathoms there occurs an oil-shale, approximately 15 ft. thick, and resting on a sandstone that gives off a large quantity of gas. The commercial value of the oil-shale cannot be estimated from the samples obtained by the method of drilling, but there is little doubt that it is one of the bands towards the top of the Oil Shale Group.

From 118 fms. to 150 fms.—the present depth of the boring —the strata are mainly sandstones, with a band of white limestone, 10 ft. thick at 126 fms. Traces of a coal occur at 139 fms. At 150 fms. a fine-grained white sandstone yields brackish water with traces of oil.

West Calder Oil Well.—In the 'Summary of Progress for 1919' an account of this boring was given to a depth of 543 fms. The present depth is 651 fms., the strata between 543 fms. and 650 fms., consisting of black shales with interbedded bands of volcanic ash. The boring is now in sandstone yielding salt water in considerable quantity. The absence of sandstones between 215 and 650 fms. is remarkable and it would appear that sandstones of the Granton Sandstone Group have not yet been reached.

Digitized by Google

III.—PETROGRAPHICAL WORK.

1. England and Wales.

As far as England and Wales are concerned most of the petrographical work has been in connection with special enquiries from private individuals and Government departments. An investigation into the size and nature of dust-particles aspirated from the air of mines and factories has been carried out at the request of the Home Office, and the results will be in due course embodied in the reports of that department. Dr. Thomas at the invitation of the Society of Antiquaries has investigated the probable source of the 34 foreign stones that constitute all that remains of the inner circle and inner horse-shoe of Stonehenge. These stones have come within the purview of many geologists, who have suggested in general terms possible sources in North and South Wales, Devon, Cornwall, and even Scotland. They were simple standing-stones, not capped by lintels, and show no signs, except in the case of one prostrate stone, of ever having been morticed, as are the sarsens of the outer circle and the trilithons. That they were dressed on the spot and considerably reduced in size has been abundantly proved by the copious fragments found in the soil during the recent excavations by H.M. Office of Works.

The most interesting feature of these stones is that of the 34 now remaining, 29 are all of the same type (blue stones) and are formed of a bluish green even textured diabase that is characterised by an abundance of irregular felspar crystals (albite oligoclase) that appear in the hand-specimen as pinkish or white spots ranging from the size of a pea to that of a hazel nut.

This spotted character, not commented upon by earlier observers, at once removes the rock in question from the generality of diabases, and renders the identification of the source a matter of greater certainty.

A spotted diabase of identical appearance, mineralogical composition and microscopic character is the dominant rock of the Prescelly Mountains in Pembrokeshire. These hills rise more or less abruptly from the plain of Western Wales and owe their form and preservation largely to the sills of diabase which extend through them from Rosebush on the west to Crymmych on the east.

Such spotted diabases are, as far as Great Britain is concerned, practically restricted to the Pembrokeshire area and therefore the Prescelly Mountains must be regarded as the most probable ultimate source of the Stonehenge ' blue stones.'

It is interesting to note that in association with the spotted diabase of Prescelly there occurs a considerable mass of banded and minutely spherulitic rhyolites. These rocks, grey in colour and weathering with a white crust in which the banding shows most clearly, are identical with three stones of finely-banded

Digitized by Google

rhyolite represented amongst the foreign stones of Stonehenge. It, therefore, appears that 32 out of the 34 foreign stones may, with little doubt, be referred to Pembrokeshire sources. The remaining examples of slaty sedimentary rocks and the micaceous sandstone of the so-called 'altar stone' are not in disagreement with a Welsh derivation.

As far as Salisbury Plain is concerned the foreign origin of these stones is unquestionable, and various theories have been propounded to explain their presence in a region so remote from all possible sources. The theory most generally accepted and first put forward by the late Prof. Judd, was to the effect that they had been transported by ice to the Plain from some region to the north; and he explained the absence of all smaller stones of the same character by assuming that these had been utilised for mill-stones, gate-posts, &c. As pointed out by Mr. Stevens and other workers, there is no evidence of the existence of any masses of rock of these types, either large or small, in Wiltshire, except within the area of Stonehenge itself. Further, the ice that was supposed to carry these boulders to Salisbury Plain would have had to select carefully from all the rocks over which it passed, not only as regards rock-type, but also as regards the size of the transported material. The idea that such rocks had been glacially carried to the Plain must be dismissed as being contrary to the mass of geological evidence. With the object of eliminating all other possible sources, especially those of a proximate nature, a careful revision was made of the rock-types represented amongst the large boulders stranded on the coastal regions of Hampshire between Selsey and Bournemouth. All specimens available including those noted by Godwin Austin, Clement Reid, Osborne White, and others, have been examined, with the result that in no case has a Stonehenge type been detected. We may assume, therefore, that these boulders, often of considerable size and occurring relatively near to Salisbury Plain were either unknown to, or disregarded by, the builders of Stonehenge. In view of the last-mentioned fact and the still more important uniformity of type presented by the Stonehenge 'blue stones' and rhyolites, the inevitable conclusion is that the stones were brought direct from their parent source by human agency.

In Pembrokeshire, boulders of these rocks, dislodged by the ice that passed over the Prescelly Mountains, lie scattered over the stopes and low ground to the south and south-east, and masses of suitable size could be easily collected. That the monoliths were derived from a glaciated region, a feature that at once rules out Devon and Cornwall as possible sources, is indicated by the recent find at Stonehenge of a large flake from one of the 'bluestones,' which shows good glacial striations.

2. Scotland.

Petrographical work in connection with the forthcoming memoir on the Island of Mull has been carried out by Dr. Thomas

Digitized by Google

and Mr. E. B. Bailey. Special attention has been paid to the classification of the basalt lavas of Sheet 44. It has been found that they are roughly divisible into two petrographical groups olivine-rich and olivine-poor respectively. Of these, varieties rich in olivine preponderate in the lower part of the volcanic pile, and the olivine-poor varieties in the upper part.

In the Ben More region the group rich in olivine is roughly 3,000 ft. in thickness, and it is clear in the field that the group poor in olivine which succeeds is of approximately the same magnitude.

In previous reports the basalts poor in olivine have been spoken of as andesites, and this appellation has not infrequently been applied to certain olivine-rich varieties that have a pale tint in the hand-specimen. The prevalence of pale lavas associated with, but distant from, the mugearite lava-zone of Ben More was, perhaps, first recognised by Sir Archibald Geikie. The pale colour is now shown to be correlated with a poor development of magnetite which results from the decomposition of olivine. In the Ben More region it would seem that the olivine of the lavas in the lower part of the olivine-rich group of basalts was more ferruginous than that of lavas on higher horizons, for it yielded on decomposition abundant secondary magnetite. It is one of the most interesting features of Mull geology that within a circle 14 miles in diameter, none of the basalt lavas have retained their olivine in a fresh condition. This circle centres on the hill-country between Glen Cannel and Glen More, and includes Ben More well within its circumference. The definite character of this phenomenon will be recognised when it is said that out of 336 olivine basalts sliced from within the circle none has retained any fresh olivine, while of 44 specimens of similar rocks sliced from outside the area in question, 34 carry this susceptible mineral in a more or less unaltered condition.

Side by side with this replacement of olivine by chlorite and serpentine, there is a widespread development of albite and epidote filling cracks and vesicles. These phenomena are attributed to pneumatolitic action connected with the Mull centre of activity. A full discussion must be deferred until the publication of the Memoir, but it is proper to say that many of the features have already been dealt with in the writings of the late Prof. Judd.

IV.—CHEMICAL WORK.

During the year work in connection with the Special Report on British Refractory Materials has been continued, and 18 fireclay analyses completed for inclusion therein.

In addition, analyses were made of one rock from Leicestershire for Memoir Sheet 169 and of eight from Aberdeen and Banffshire for Memoir on Sheets 86 and 96, the details of seven being included in this Report.

Digitized by Google

As examples of the composition of British fireclays analyses of six are given below :—

Old Mine fireclay, black, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4354; Lab. No. 610.

Old Mine fireclay, white, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4355; Lab. No. 611.

Fireclay, No. 1 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4357; Lab. No. 613.

Fireclay, No. 4 New Mine, Stourbridge.—One-in. Ordnance map (New Ser.), 167; 6-in. Staffordshire, 71, S.W. Museum No. 4356; Lab. No. 612.

'*Nonsuch Fire-earth*'—brown-green variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5703; Lab. No. 653.

'*Nonsuch Fire-earth*'—'white' variety, Reading Beds, Epsom.—One-in. Ordnance map (New Ser.), 286; 6-in. Surrey, 19, N.W. Museum No. 5709; Lab. No. 659.

Lab. No.	610	611	613	612
SiO_2	45·22	77·71	58·18	62·67
TiO_2	1·08	1·38	1·27	1·15
Al_2O_3	31.32	13·46	26·36	22·30
Fe_2O_3	1·76	1·04	1·61	2·90
MnO	·03	·02	·03	·03
CaO	·34	·05	·29	·23
MgO	·51	·23	·69	·66
K_2O	·94	·06	1·67	·48
Na_2O	·23	·35	·20	·38
Li_2O	trace	trace	trace	trace
H_2O at 105° C.	3·00	·91	1·56	1·61
H_2O above 105° C.	11·30	4·81	8·19	7·86
P_2O_5	·07	·05	·12	·07
FeS_2	·01	·05	·04	·02
Organic matter	4·18	·12	·21	·12
CO_2	·04	·03	·01	·04
Total	100·03	100·27	100·43	100·52
Loss on ignition	18·52	5·94	10·17	9·58

Lab. No.	653	659
SiO_2	85·65	91·30
TiO_2	·36	·35
Al_2O_3	5·44	3·77
Fe_2O_3	4·21	1·98
FeO	·23	·11
MnO	·03	·02
CaO	·40	·34

Digitized by Google

Lab. No.	653	659
MgO	·65	·44
K_2O	1·19	·60
Na_2O	·10	·01
Li_2O	nt. fd.	nt. fd.
H_2O	1·98	1·32
P_2O_5	·05	·03
FeS_2	nt. fd.	nt. fd.
CO_2	nt. fd.	nt. fd.
Total	100·29	100·27

Results calculated on samples dried at 105° C.

The following are analyses of rocks of the Older Igneous Series of Portsoy and district :—

Pyroxenite.—Line of crags, inside west edge of Whitehill Plantation, 300 yds. W. by N. of Whitehill Farm; ¾ mile W. of Rothiemay Station. One-in. map, 86; 6-in. Aberdeen, 17, S.W. Slice No. S. 20363; Lab. No. 640.

Labradorite Rock.—Knob, just above high-water mark, 200 yds. W.S.W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 2213; Lab. No. 639.

Epidiorite.—Sea-cliff, 70 yds. W. of gasworks, Portsoy. One-in. map, 96; 6-in. Banff, 3, N.E. Slice No. S. 20364; Lab. No. 641.

Lab. No.	640	639	641
SiO_2	49·76	48·85	48·65
TiO_2	·11	·29	1·30
Al_2O_3	2·70	26·51	14·92
Fe_2O_3	2·56	1·28	1·31
Cr_2O_3	·34	nt. fd.	nt. fd.
V_2O_3	·07	nt. fd.	nt. fd.
FeO	4·26	·95	8·03
MnO	·17	·13	·11
(CoNi) O	nt. fd.	·03	nt. fd.
BaO	nt. fd.	·01	trace
CaO	15·56	12·19	8·79
MgO	22·03	1·64	8·92
K_2O	·18	·96	1·76
Na_2O	·10	3·64	2·56
Li_2O	nt. fd.	nt. fd.	nt. fd.
H_2O at 105° C.	·24	·25	·23
H_2O above 105° C.	1·85	1·57	1·26
P_2O_5	·05	·08	·17
FeS_2	nt. fd.	nt. fd.	nt. fd.
Fe_7S_8	nt. fd.	nt. fd.	1·07
CO_2	·05	1·96	·96
Total	100·03	100·34	100·04

Anal.—E. G. Radley.

Digitized by Google

Below are four analyses of the Younger Igneous Series forming part of the Huntly Igneous Mass :—

Peridotite.—Quarry on east side of road, midway between Boghaugh and Broadlands, ⅓ mile N.E. of Broadlands, 3 miles W.N.W. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20360; Lab. No. 634.

Olivine Gabbro.—Right bank of River Deveron, 200 yds. N. of Cairnford Bridge, 2¾ miles W. by N. of Huntly P.O. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 19680; Lab. No. 635.

Troctolite.—Craighead Quarry, in wood N. of road, ⅓ mile E. of Cairnford Bridge, 2 miles W. of Huntly. One-in. map, 86; 6-in. Aberdeen, 25, N.E. Slice No. S. 20361; Lab. No. 636.

Norite.—Ladysmith Quarry, W. of Keillenknowes, 4 miles N.N.E. of Huntly. One-in. map, 86; 6-in. Aberdeen, 17, S.E. Slice No. S. 20362; Lab. No. 637.

Lab. No.	634	635	636	637
SiO_2	35·72	48·11	44·29	48·58
TiO_2	·36	·75	·09	3·44
Al_2O_3	10·99	17·86	25·26	13·82
Fe_2O_3	3·73	·43	·04	1·14
Cr_2O_3	·37	·13	·09	nt. fd.
V_2O_3	·09	·05	·03	nt. fd.
FeO	6·37	5·20	3·28	12·73
MnO	·06	·30	·25	·32
(CoNi) O	nt. fd.	nt. fd.	nt. fd.	nt. fd.
BaO	trace	nt. fd.	trace	nt. fd.
CaO	3·28	12·42	11·32	9·43
MgO	26·62	9·53	7·94	5·21
K_2O	·43	·64	·49	·76
Na_2O	·58	2·34	2·30	2·87
Li_2O	nt. fd.	nt. fd.	trace	nt. fd.
H_2O at 105° C.	·58	·14	·33	·05
H_2O above 105° C.	8·72	·84	2·57	·36
P_2O_5	·14	·07	·07	·64
FeS_2	·12	·11	·12	·08
Fe_7S_8	1·49	·68	·95	·38
CO_2	·38	·54	·83	·37
Total	100·03	100·14	100·25	100·18

Anal.—E. G. Radley.

Quartz-Diorite Porphyrite.—Elongated boss, unconformably overlain by Keuper Marl and drift. N.W. corner of Sapcote Quarry. One-inch map 169. Six-inch Leicester, 43 N.E. Slice No. E. 12011. Lab. No. 633.

SiO_2	61·84
TiO_2	·66

Digitized by Google

Al_2O_3	15·51
Fe_2O_3	1·90
FeO	2·84
MnO	·08
(CoNi)O	nt. fd.
BaO	·02
CaO	5·03
MgO	3·22
K_2O	1·98
Na_2O	4·12
Li_2O	nt. fd.
H_2O at 105°C	·34
H_2O above 105°C	1·97
P_2O_5	·21
FeS_2	·10
CO_2	·52
Total	100·34

Anal.—E. G. Radley.

V.—PALÆONTOLOGICAL WORK.

1. England and Wales.

The collections of fossils have been enriched by some valuable donations. Miss C. A. Raisin presented a large collection of Jurassic Mollusca, formerly in the possession of the late W. H. Hudleston. The specimens are well localized and are of fine quality, while many of them are of special interest, since they serve to illustrate some of Hudleston's published work. Mr. G. W. Lamplugh presented his fine collection of sponges from the Upper Chalk of Yorkshire. This comprises many specimens suitable for museum exhibition, and a wealth of material for special study. A collection of 500 specimens of Mollusca from the Crag of Oakley was received from Mr. F. W. Harmer.

Dr. Kitchin and Mr. Pringle examined several sections in the Gault of different localities. At Copt Point, Folkestone, they searched for the horizon characterised by the *catillus*-fauna, which occurs in the Rostratus Beds of sandy facies in Wiltshire and the Isle of Wight. It was found to occupy a position at Folkestone near the base of Price's Bed XI., about 15 ft. above the top of Bed IX. In a temporary opening made in an old clay-pit at Long Crendon, in Buckinghamshire, the clay was found to be Upper Gault, showing an ochreous basement-bed almost identical in character with that seen in the case of the overlapping Upper Gault near Leighton Buzzard, which there rests upon the uppermost parts of the Lower Greensand. At Long Crendon, the basement-bed occupies a position less than 3 ft. above a Purbeck limestone.

Digitized by Google

Visits were also made to Cambridge, to examine a section in the Cambridge Greensand and Gault, and to the Leighton Buzzard neighbourhood, to continue observations on the Gault and contiguous deposits, begun unofficially by Dr. Kitchin and Mr. Pringle. At the Norman Cement Co.'s large pit at Cambridge, some excavations had laid bare the Cambridge Greensand, which is rarely so well seen. The phosphate-bed was observed to rest upon an uneven and bored floor of unfossiliferous Gault. It was not possible to determine the exact horizon of this uppermost Gault, but it is highly probable from its lithological characters and the absence of fossils in it, that it corresponds with a level well above the base of Bed XI. of Folkestone. This is in agreement with the observations made by Prof. Fearnsides many years ago in the Barnwell pit. The amount of erosion to which the Gault was subjected at these localities was, therefore, less than in some other pits at one time opened along the outcrop, where the phosphate-bed contained some of the fossils of Bed IX. of Folkestone, in *remanié* condition.

Further collecting of fossils from the nodules of the Tardefurcata Bed, below the Interruptus Zone south of Leighton Buzzard, has added considerably to our knowledge of the fauna of that horizon, which is there well characterised by species of *Leymeriella*. The results of collecting from the phosphate-nodules in the sands immediately below the Gault at West Dereham, Norfolk, favour the view that at that locality the Tardefurcata Zone is present below the Interruptus Clay, as in Bedfordshire.

Mr. Pringle visited the sites of numerous borings during the year. The results of the borings at Bourne End, Marlow and Slough have been incorporated in the Memoir on the Water Supply of Buckinghamshire and Hertfordshire. Upwards of a dozen borings in Norfolk have given interesting geological information, which has not yet been made available for publication. Light has been thrown on the underground extension of the Jurassic formations in that county. A boring at North Ferriby, near Hull, has shown that the Red Chalk there rests upon a clay which belongs either to the basal part of the Kimmeridge Clay, or to the upper part of the Corallian Series. The results of Mr. Pringle's examination of the cores at a deep boring at Yate, Gloucestershire, are published herewith as an Appendix (p. 92).

A piece of core from the Keele Beds in a boring at Slang Lane, Wellington, submitted to Mr. Pringle for examination, yielded a new insect-wing. This has been described by Mr. H. Bolton as *Archimylacris pringlei* in a paper read before the Geological Society.

Good progress has been made in museum revision-work. Mr. Buckman has continued the re-naming of the Jurassic ammonites. Mr. Chatwin has carried out curatorial work on

Digitized by Google

the collection of Tertiary Mollusca, and has devoted much time to the important task of registration.

The following specimens in the Museum have been figured and described :—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1918.

(PUBLISHED 1920.)

A Monograph of the British Ordovician and Silurian Bellerophontacea. (Part 1.)

By DR. F. R. COWPER REED, M.A.

Sinuites anceps *Reed*, pl. i, figs. 1, 1a, 2, 2a, p. 5.
„ bilobatus (*J. de C. Sow.*), pl. i, figs. 8, 8a, b, p. 7.
„ elongatus (*Portl.*), pl. i, figs. 12, 12a, 13, 13a, p. 9.
„ semirugosus *Reed*, pl. ii, figs. 13, 14, 16, p. 13.
„ soudleyensis *Reed*, pl. ii, figs. 18, 18a, b; pl. iii, fig. 3, p. 13.
Oxydiscus acutus (*J. de C. Sow.*), pl. iv, figs. 1, 1a, b, 2, 2a, p. 19.
„ ? llanvirnensis (*Hicks*), pl. iv, figs. 10, 10a, 11, 11a, p. 22.
Cyrtolites nodosus (*Salt.*), pl. v, figs. 1, 1a-c, 2, 2a, b, p. 25.
„ „ *var.* llandoveriana *Reed*, pl. v, figs. 3, 3a, 4, p. 26.
Kokenospira lingualis (*Salt.*), pl. vi, fig. 16; pl. vii, figs. 1, 1a, b, p. 35.
Tetranota hippopus (*Salt.*), pl. viii, fig. 16, p. 43.

The Pliocene Mollusca of Great Britain. Volume ii., Part 1.

By MR. F. W. HARMER, M.A.

Scala (Spiniscala) trevelyana (*Leach*), pl. xlviii, fig. 14, (2 views), p. 528.
„ (Lamelliscala) frondosa (*J. Sow.*), pl. xlviii, fig. 22, (2 views), p. 532.
Pyrgulina scalaris (*Philippi*), pl. xlix, fig. 43, (2 views), p. 577.
„ spiralis (*Montagu*), pl. xlix, fig. 44, (2 views), p. 578.
Alvania (Massotia) lactea (*Michaud*), pl. l, fig. 41, (2 views), p. 621.
„ (Galeodina) carinata (*Da Costa*), pl. l, fig. 44, (2 views), p. 620.
Manzonia costata (*Adams*), pl. l, fig. 48, (2 views), p. 624.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY VOLUME LXXVI.

BY DR. F. J. NORTH.

Tylothyris laminosa (*M'Coy*), pl. xiii, fig. 16, p. 197.
Spirifer plicatosulcatus *North*, pl. xiii, figs. 17a, b, p. 193.

IN THE GEOLOGICAL MAGAZINE, VOLUME LVII., 1920.

By DR. F. R. COWPER REED, M.A.

Homalonotus (Burmeisterella) elongatus (*Salt.*), p. 343.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME V.

By DR. C. W. ANDREWS, F.R.S.

Patanemys bartonensis *Andrews*, text-fig. 2, p. 149.

Digitized by Google

IN TYPE AMMONITES, VOLUME iii.

By MR. S. S. BUCKMAN.

Retenticeras retentum (*Simpson*), pl. clxvi, figs. 1, 2.
Pavloviceras bathyomphalum *S. Buckm.*, p. 18.
„ omphaloides (*J. Sow.*), p. 18, (2 specimens).

IN THE REPORT OF THE YORKSHIRE PHILOSOPHICAL SOCIETY, 1919.

British Fishes and Reptiles—Pliocene to Holocene.

By MR. ALFRED BELL.

Notidanus griseus ? *Cuv.*, pl. i, fig. 4, p. 9.
Acipenser toliapicus *Ag.*, p. 12.

IN THE ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DU NORD, LILLE, TOME XLIII.

By DR. P. PRUVOST.

Leaia salteriana *R. Jones*, pl. ii, figs. 1-3; text-fig. 2, p. 262.

2. SCOTLAND.

Fossils were collected from Carboniferous Rocks in the Central coalfield, and from Mesozoic areas in the island of Mull and Sutherlandshire.

The Carboniferous fossils were obtained partly from natural exposures and partly from borings. In several instances the determination in borings of important horizons, about which there was doubt, was successfully achieved from palæontological evidence.

A preliminary examination of fossils collected by Mr. Manson on the west coast of Mull has led to the recognition of Rhaetic, Hettangian, and Sinemurian strata referred to on p. 35.

Detailed collecting, on zonal lines, was made in the Jurassic rocks of the Brora district in Sutherland, but as the work was undertaken late in the year, the critical examination of the fossils could not be begun in time to be summarised here.

VI.—PHOTOGRAPHIC WORK.

In England and Wales 26 views of geological subjects have been added to the collections.

In Scotland 170 negatives of landscapes of special geological interest in the counties of Argyll, (Morvern and Mull), Forfar and Kincardine were obtained.

VII.—MUSEUM OF PRACTICAL GEOLOGY.

In illustration of Vol. VII. of the 'Special Reports,' a temporary exhibit has been prepared of the lignites, jets, Kimmeridge oil-shale, mineral oils and cannel coals of Great

Digitized by Google

Britain. This exhibit, which includes a sample of the oil from the Hardstoft boring in Derbyshire, has been the object of much public interest.

Dr. J. Morrow Campbell lent a large suite of specimens in illustration of his paper on the Tungsten Deposits of Burma, and Mr. W. S. Lockhart has lent a Chinese screen, which is a very beautiful example of skilful artistic treatment of a colour-banded slate.

Although much work is still necessary before the Museum recovers from the disorganisation caused by the war, it has been possible this year to make all parts accessible, and the work of arrangement is now in progress.

List of Donations during the year 1920.

Acton, A., Esq.—Two nodules from sandy limestone shales, also sections and specimens of silica.

Anderson, Dr. Victor C.—Specimen of oil shale from Grand Valley, Colorado, with photographs.

Andrews, Charles T., Esq.—Specimens of phenakite crystals, also enhydros, from Brazil.

Barrow, Mrs. R.—A fine specimen of *Ammonite* from the Mammillatus Bed of West Dereham, Norfolk.

Bolckow, Vaughan & Co., Messrs.—A specimen of fused silica-brick, also akermanite crystals.

Brown, G. F., Esq.—A specimen of *Lima hoperi* Mant., from the Upper Chalk of Purley.

Buck, the Hon. E. C., M.Inst.C.E., F.G.S.—specimens of petroleum (pitch) from the Waini and Pomeroon districts, British Guiana.

Carley, G., Esq.—A fine group of pyrites crystals from the Gaurano Mine, Tuscany.

Carruthers, R. G., Esq., F.R.S.E.—Two specimens and a series of thin sections of *Cryptophyllum hibernicum* R. Carr., from the Carboniferous Limestone of Bundoran, Donegal Bay, Ireland.

Dewey, H., Esq., F.G.S.—Specimens of marcasite and pseudomorphs, also ancient slags.

Edge, Lieut. A. B.—A specimen of siliceous sinter, from Devonshire.

Garnett, C. S., Esq.—Two small specimens of red fluorspar from Ashover.

Gomme, A. T., Esq.—Part of a dermal spine of *Polacanthus*, from the Wealden of Cuckfield, Sussex.

Greenly, Dr. E.—A specimen of Asteroid from the Middle Calcareous Grit of Filey Brig, Yorkshire.

Hackney, Noel G., Esq., M.Inst.M.M.—A drawing of the Southampton Common Well, by Henry Penrose, Engineer, 1842, showing strata to 560 feet. Scale, 1 inch—4 feet.

Hall, T. Clifford, Esq., Assoc.M.Inst.M.M., F.G.S.—Minerals and rock specimens from Abyssinia; also specimen of tin vein from Roche, Cornwall.

Harmer, F. W., Esq., M.A., F.G.S.—A large series of Crag Mollusca from Oakley, Suffolk.

Holloway & Co., Ltd., Messrs. G. T.—Cobaltite from the Cloncurry district, Queensland, Australia.

Hooker, Lady.—Copper ore and graphite from Sikkim.

Kidner, N. W., Esq.—A fragment of upper jaw of the crocodilean genus *Steneosaurus*, from the Cornbrash near Thrapston.

King, W. B. R., Esq., M.A., F.G.S.—Seven specimens of *Griffithides shunnerensis* King, from the Millstone Grit of Shunner Fell Well, near Hawes, Yorkshire. Also 6 specimens of volcanic rocks from the Rhine valley.

Digitized by Google

KITCHIN, F. L., ESQ., M.A., PH.D., AND PRINGLE, J., ESQ., F.G.S.—A series of fossils and rock-specimens from the Lower Greensand, Gault and Cenomanian of the Leighton Buzzard district.

LAMPLUGH, G. W., ESQ., F.R.S.—A large suite of fossils (mostly sponges) from the Upper Chalk of Yorkshire and a few fossils from the Red Chalk of Yorkshire.

LAVER, H. E., ESQ.—Two boxes of Chinese paints.

LEIGH, THE RIGHT. HON. LORD.—Specimens of pyrrhotite from Griqualand.

LIBERIAN DEVELOPMENT CO., THE.—Specimens of phenakite sand from Liberia.

MARSHALL, FRANCIS, ESQ.—Pyrites on quartz.

MAYO, H. J. A., ESQ.—A fossil cone from the Ferruginous Sands of Shanklin, Isle of Wight.

MERRICKS, FRANK, ESQ., C.B.E., A.R.S.M.—A gold nugget with crystal faces, mounted as a pin.

MESOPOTAMIA, THE CIVIL COMMISSIONER IN.—A set of economic rock specimens from Mesopotamia and Southern Kurdistan. (Collected by A. H. Noble, Esq.).

NEWBOLD, MRS. ELEANOR T.—Model of a silver mine at Guanajuato, Mexico.

OSMAN, C. W., ESQ.—Crystals of inyoite from New Brunswick. Granite specimens from boring at 'Ontie Down,' Chagford. Model of twin crystal of pyrites.

OWENS, DR. J. S., F.G.S.—A fine example of artificial percussion cones in flint.

PAIN, MESSRS. A. C. D., AND R. S.—Three quartz pseudomorphs after octahedral scheelite crystals, from South Zeal, Sticklepath, Okehampton, Devonshire.

PENTLAND, THE RIGHT HON. LORD.—A walking stick of black limestone, silver mounted, with inscription 'Presented to H.E. Lord Pentland by D. Kristna Rao.'

PERKIN, DR. F. MOLLWO, C.B.E., PH.D., F.I.C.—Specimens of calcite from Nottingham.

PICKERING, CAPT.—Specimens of 'boxstone' from Wiltshire.

PRINGLE, J., ESQ., *see* KITCHIN, DR. F. L.

RAISIN, MISS C. A., D.SC., F.L.S., F.G.S.—A fine collection of about 4,000 fossils, chiefly Jurassic mollusca, formerly in the possession of the late W. H. Hudleston, F.R.S.

REINHOLD, DR. TH.—Two specimens of limestone used for lime at Maastrict and Kinrade, Holland.

RENWICK, R., ESQ.—Specimen of Stammarhan roofing stone; paving stone with ripple marks; paving stone with circular casts.

RODDA, MRS. (per W. WHITAKER, ESQ.)—Felspar twin.

SANDERS, A. B., ESQ.—Specimen of manganese ore from Brazil.

SCHAVERIEN, —., ESQ.—Three specimens of black spinel: (*a*) raw material, (*b*) cut but unpolished, (*c*) polished.

SMITH, BERNARD, ESQ., M.A.—Specimens of blende and calcite from Shropshire.

SOAMES, E. R., ESQ.—Specimens of *Stigmaria ficoides* from the Ganister of Wolsingham.

SOUTH DURHAM, STEEL AND IRON CO., LTD.—Specimens of slag, etc.

STAMP, L. DUDLEY, ESQ., M.SC.—Three specimens of associated lead and zinc ores from Lontzen Mine, Belgian Prussia.

STRAHAN, SIR AUBREY, K.B.E., F.R.S., etc.—Calamine from Holywell, and hæmatite from the Coal Measures near Frizington.

TEMPEST, P. C., ESQ., C.B.E., M.INST.C.E.—A series of photographs of the landslip in Folkestone Warren, with descriptive map.

WARREN, A., ESQ.—Specimen of picrite from Knowle Hill, Newton Abbot, Devon.

Digitized by Google

WARREN, S. HAZZLEDINE, ESQ., F.G.S.—A series of specimens, mostly fossils, from certain wells in or near London. A large rough-worked block from the implement-bearing scree, Graig Lwyd, near Penmaenmawr; also a more finished but imperfect implement. Also two Roman blocks of calcareous tufa from East Wear Bay.

WHITAKER, W., ESQ., B.A., F.R.S.—A necklace of clear facetted amber beads.

WAY, REV. DR. J. P.—A specimen of pseudomorphous quartz from South Zeal Mine, Cornwall.

WHITE, FRANKLIN, ESQ., M.INST.M.M.—Mineral specimens from Broken Hill, Rhodesia.

WILSON, M. E., ESQ.—A series of samples representing the products of the Canadian China Clay Company, Amhurst Township, Ottawa, Canada.

WRIGHT, C. S., ESQ.—A twinned crystal of albite.

VIII.—MAPS AND MEMOIRS, ETC., PREPARED AND PUBLISHED.

The following is a list of the Maps and Memoirs issued by the Geological Survey during the past year.

ENGLAND AND WALES.

I.—MAPS.

SIX-INCH REFERENCE MAPS.

The following 24 standard copies of Six-inch quarter-sheets have been made from the field copies, and are available for reference :—

Hertfordshire, 19 S.E.; 20 S.W., S.E.; 27 N.E., S.E.; 28 N.W., N.E., S.W., S.E.; 34 N.E., S.E.; 35 N.W., N.E., S.W., S.E.; 39 N.E., S.E.; 40 N.W., S.W.

Kent, 8 S.W.

London, 8 S.W., S.E.

Middlesex, 1 N.E., S.E.

II.—MEMOIRS.

PUBLISHED MEMOIRS.

Special Reports on the Mineral Resources of Great Britain :—

Vol. VI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Resources and Geology. 2nd Edition. 241 pp.; 3 plates; 8 text-figures. 1920. Price 7*s.* 6*d.* net.

Vol. VII.—Mineral Oil, Kimmeridge Oil-Shale, Lignites, Jets, Cannel Coals, Natural Gas. England and Wales. 2nd Edition. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., with contributions by W. Gibson, D.Sc., H. Dewey, B. Smith, M.A., C. E. N. Bromehead, B.A., J. Pringle. 125 pp.; 1 plate; 7 text-figures. 1920. Price 5*s.* net.

Vol. XII.—Iron Ores (*contd.*): Bedded Ores of the Lias, Oolites and Later Formations in England. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp.; 8 plates; 12 text-figures. 1920. Price 12*s.* 6*d.* net.

Vol. XIII.—Iron Ores (*contd.*): Pre-Carboniferous and Carboniferous Bedded Ores of England and Wales. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S., W. Gibson, D.Sc., T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp.; 3 plates, 10 text-figures. 1920. Price 7*s.* 6*d.* net.

Digitized by Google

Vol. XIV.—Refractory Materials: Fireclays. Resources and Geology. 243 pp.; 4 plates, 13 text-figures. 1920. Price 8*s.* net.

Vol. XV.—Arsenic and Antimony Ores. By Henry Dewey, with contributions by J. S. Flett, O.B.E., LL.D., D.Sc., F.R.S., and G. V. Wilson, B.Sc. 59 pp.; 1 plate, 2 text-figures. 1920. Price 3*s.* net.

Vol. XVI.—Refractory Materials: Ganister and Silica-Rock—Sand for Open-Hearth Steel Furnaces—Dolomite. Petrography and Chemistry. By Herbert H. Thomas, M.A., Sc.D., A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp; 7 plates, 6 text-figures. 1920. Price 5*s.* net.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for 1919. 70 pp.; 3 text-figures. 1920. Price 2*s.* 6*d.* net.

The Geology of Anglesey. By Edward Greenly. 980 pp., 60 plates; 17 folding-plates, 246 text-figures. 1919. In two volumes. Price 3*l.* 3*s.* net.

SCOTLAND.

I.—Maps.

Six-inch Reference Maps.

The following copies of 6-inch maps have been completed and deposited in the office for reference:—

Aberdeen, 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 43 N.W., N.E.; 44 N.W., N.E.
Renfrew, 15 N.E.
} Solid and Drift of each.

The revision work of the Silurian areas of the Southern Uplands of Scotland has been added to the following 6-inch clean copies (Old Series Maps) and these are now completed and deposited in the office for reference:—

Kirkcudbright, 30 N.W., N.E., S.W., S.E.; 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 42 N.W., N.E., S.E.; 43 N.W., N.E., S.W., S.E.; 48 N.E.

Wigtown, 1 S.W., S.E.; 2 S.W., S.E.; 3 S.W.

II.—Memoirs.

Published Memoirs.

Summary of Progress for 1919. *See* above.

Special Reports on the Mineral Resources of Great Britain:—

Vol. XI.—Iron Ores (*cont.*): The Iron Ores of Scotland. By M. Macgregor, B.Sc., G. W. Lee, D.Sc., G. V. Wilson, B.Sc., with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp; 18 text-figures. 1920. Price 10*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area IV. Paisley, Barrhead, Renfrew, and the Western Suburbs of Glasgow North and South of the Clyde. By L. W. Hinxman, B.A., F.R.S.E., E. M. Anderson, M.A., B.Sc., and R. G. Carruthers, F.G.S. 110 pp.; 8 plates, 5 text-figures. 1920. Price 6*s.* net.

The Economic Geology of the Central Coalfield of Scotland. Area VII. Including the Districts of Rutherglen, Hamilton and Wishaw. By the late C. T. Clough, M.A., LL.D., the late J. S. G. Wilson, E. M. Anderson, M.A., B.Sc., and M. Macgregor, M.A., B.Sc., with contributions by R. G. Carruthers and C. H. Dinham, B.A. 144 pp.; 6 plates, 4 text-figures. 1920. Price 7*s.* 6*d.* net.

The Mesozoic Rocks of Applecross, Raasay and North-East Skye. By G. W. Lee, D.Sc., with contributions and an Appendix by S. S. Buckman, F.G.S. 93 pp.; 10 plates, 1 text-figure. 1920. Price 6*s.* net.

Digitized by Google

APPENDIX I.

The Banffshire Coast Section of the Highland Schists.

By H. H. Read.

It is fortunate for the study of the Highland schists of North-East Scotland that, in the Banffshire Coast Section (Sheet 96), there is available what is probably the most continuous section of these rocks in the Highlands. This section (Fig. 2) is over 25 miles in length, with but a few trifling gaps, all of which can be filled by adjacent inland exposures. Except at a few localities, the cliffs are easily accessible and, together with the rocky foreshore, provide magnificent sections for study. The run of the coast line is west and east, almost at right angles to the strike of the Highland schists—a circumstance showing once more the exceptional nature of this section. Upon its interpretation must depend the interpretation of the somewhat poorly exposed Buchan, Strathbogie and Lower Banffshire districts of the North-East Highlands.

No modern work has been done on this section. Amongst the early workers are numbered Jameson,[1] Prestwich,[2] Hay Cunningham,[3] Harkness,[4] and Wallace.[5] The ground was originally mapped by Dr. John Horne, and his results were published in 1895 as the present One-inch Sheet 96 (Banff) of the Geological Survey Map of Scotland.

The lithological sequence of the Highland Schists of the Banffshire coast section from west to east is as follows :—

Keith Division	(*a*) Cullen Quartzite	a^1—Findochty Beds.
		a^2—Logie Head Beds.
	(*b*) West Sands Garnetiferous Mica-Schist.	
	(*c*) Findlater Flags.	
	(*d*) Crathie Point Calcareous Group.	
	(*e*) Garron Point Actinolitic Schists.	
	(*f*) Sandend (Black Schist-Limestone) Group.	
	(*g*) Durn Hill Quartzite.	
	(*h*) Portsoy Group.	
	(*j*) Cowhythe Gneiss.	
Banff Division	(*k*) Boyne Limestone.	
	(*l*) Whitehills Group.	
	(*m*) Boyndie Bay Group.	
	(*n*) Macduff Group.	

[1] Robert Jameson, 'Mineralogy of the Scottish Isles,' vol. ii, 1800, pp. 267–279.

[2] J. Prestwich, 'On the Structure of the neighbourhood of Gamrie, Banffshire,' *Trans. Geol. Soc.*, vol. v, 1840, p. 141.

[3] J. H. Cunningham, 'Geognostical Account of Banffshire,' *Trans. High. Agric. Soc., Scot.*, vol. xiv, 1843, pp. 447–502.

[4] R. Harkness, 'On the Metamorphic Rocks of the Banffshire Coast,' *Quart. Journ. Geol. Soc.*, vol. xviii, 1862, pp. 331–336.

[5] T. D. Wallace, 'The Geology of Rathven and the Enzie,' *Trans. Edin. Geol. Soc.*, vol. iii, 1880, p. 331.

Digitized by Google

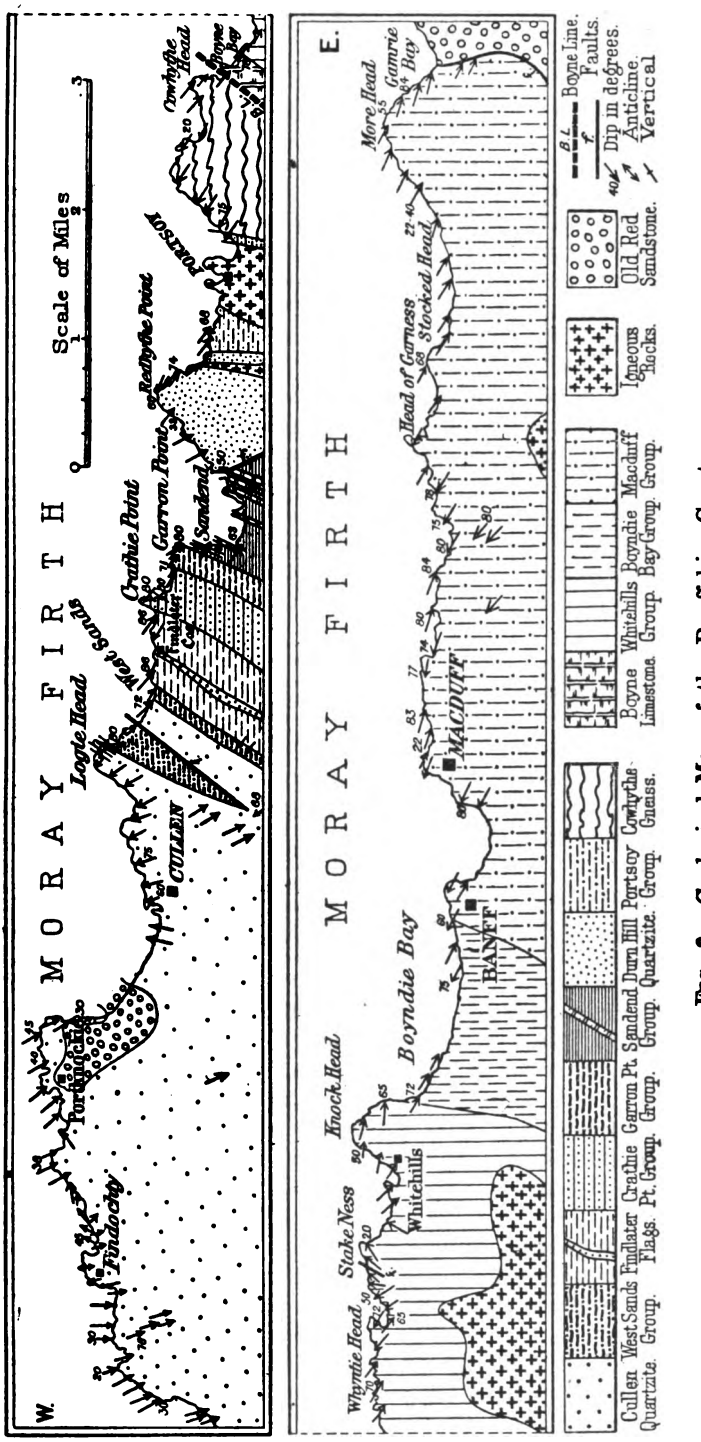

FIG. 2.—Geological Map of the Banffshire Coast.

Digitized by Google

A short description of these groups will be given, and the reasons for the separation into two divisions developed, in what follows.

KEITH DIVISION.

(a) *Cullen Quartzite.*—This group forms the coast from Buckie eastwards to Logie Head, 1 mile east of Cullen. A detached area is found, with a breadth of 500 yds., at Sunnyside ¼ mile east of Logie Head. From Buckie eastwards to Portknockie, the coast runs parallel with the strike, and practically the same beds—the *Findochty Sub-group*, are seen all the way. The strike is about E.N.E.—W.S.W.; the prevailing dip is to the S.S.E., at rather low angles. The staple rock of the Findochty Sub-group is a very fine-grained granulitic quartzite of a white, grey or pinkish colour. The rock is massive and in thick beds; colour banding and the production of white mica in zones of intense folding have been noted. In slice, orthoclase is found to be almost always present in small amount in these rocks. Interbedded with the quartzite are many bands of dark, almost black, garnetiferous mica-schist; such bands seldom reach more than a foot or so in thickness, and are usually much less. In slice, these schists are composed of coarse, granulitic quartz, scarce orthoclase, abundant yellow-green to greenish-black biotite, scarcer muscovite and spongy porphyroblasts of pink garnet.

The remaining part of the Cullen Quartzite is formed by the *Logie Head Sub-group.* These rocks are thinly bedded and flaggy and point to the oncoming of the great flag groups to the east. The strike is about N.E.—S.W., the dip is vertical, or at high angles to the N.W. or S.E. The members of this sub-group are a rapidly alternating series of different kinds of rocks, each band averaging perhaps one or two feet in thickness. The highly crystalline granulitic quartzite of the Findochty Sub-group is still common, but here forms thinner bands. With these are associated dark, pinkish micaceous quartzites, mealy-weathering quartz-schists, buff quartzites speckled with small garnets, banded grey quartzites with thin micaceous layers, very finely banded grey and white flaggy beds with much silvery mica on the flag surfaces, very garnetiferous dark mica-schists, and thin bands of epidote-hornblende-granulite.

At the east head of Logie Head, a good transition into the next group—the West Sands garnetiferous mica-schists—is to be seen, the change taking place by the interstratification of granulitic quartzites and dark garnetiferous mica-schists, typical Cullen Quartzite rocks gradually giving place to typical West Sands schists.

Eastwards of Logie Head, the West Sands Group makes the coast for 500 yds., and then is faulted out by a fault well seen between tide marks. This fault brings on the Cullen Quartzite again for about 500 yds. until these rocks pass, by a similar

Digitized by Google

transition phase, eastwards into the main outcrop of the West Sands Group at West Sands.

(b) *West Sands Garnetiferous Mica-Schist.*—At West Sands this group has an outcrop 120 yds. wide, with a high dip to the S.E. The group also forms the shore section for 500 yds. between the two outcrops of Cullen Quartzite, as already mentioned. In both places a gradual passage from Cullen Quartzite is seen; eastwards from West Sands, the West Sands Group passes gradually into the Findlater Flags. In West Sands, the staple rock of the group is a dark garnetiferous mica-schist, with quartzose bands and quartz kernels. In the centre of the outcrop there is a *calcareous* zone made up of thin, siliceous limestone bands, aggregating in all perhaps 2 or 3 ft. in thickness. In slice, the staple garnetiferous mica-schist is composed of two micas, quartz and garnet. The garnet forms porphyroblasts usually better shaped in the finer grained rocks.

(c) *The Findlater Flags.*—This group follows evenly eastwards from the West Sands Group and, by the incoming of calcareous material, it passes evenly into the Crathie Point Calcareous Group on its eastern margin. It forms the shore section for about 1,000 yds.; dips are high, usually to the S.E., but occasionally to the N.W. Throughout its outcrop, this group is composed of grey quartzose beds separated into flags by the development of mica on plane surfaces. Usually individual flags are about an inch or so in thickness. In slice, the typical flags are seen to be plane-foliated micaceous granulites composed of quartz and parallel plates of biotite and muscovite; the muscovite is occasionally set in large plates athwart the foliation. Garnet is seen in many slices. At Findlater Castle there is a narrow band of white, highly crystalline pure quartzite which, in slice, is seen to be composed of large sutured grains of quartz, with a very small quantity of white scaly mica.

(d) *The Crathie Point Calcareous Group.*—This group follows eastwards from the Findlater Flags, and forms the coast section between Crathie Point and Garron Point. Its width across the strike is about 570 yds.; dips are usually over 80°, and are predominantly towards the west. The main rock of the group is a pale, calcareous mica-schist, often weathering with a honeycombed yellow crust. In slice, this rock is a calc-biotite-schist, composed of about 75 per cent. calcite together with biotite, and quite subordinate quartz grains. With this calcareous flag type there are associated a few bands of very coarse, quartz-kernelled, kyanite-biotite-gneiss. Thin bands of garnet-staurolite-schist are also encountered. Towards its eastern margin, this group contains a few bands of actinolite-schist, which becomes the dominant rock in the succeeding Garron Point Group.

(e) *Garron Point Actinolitic Schists.*—This group follows evenly from the Crathie Point Group, and passes eastwards into the Sandend Group, in which rock-types characteristic of the Garron

Digitized by Google

Point Group still persist. The width of the outcrop across strike is about 330 yds. The general dip is between 70° and 80°, and is either to the S.E. or N.W. The characteristic rock of this group is a dark, lustrous, poorly schistose rock in which there is a great development of blades of dark actinolite in felted masses, aggregates, or subradiate groupings.

Similar rocks occur at the eastern margin of the Crathie Point Group and throughout the Sandend Group, and show the essential unity of this part of the Keith Division. The actinolite-schists, unquestionably of sedimentary origin, represent the effect of regional metamorphism on an impure calcareous rock. In slice, they are composed of quartz, biotite and calcite as a ground-web, in which are set large porphyroblasts of pale green or almost colourless actinolite. With the actinolite-schists are associated flaggy micaceous quartzites and lustrous fine-grained dark grey schists with moiré surfaces.

(f) *The Sandend (Black Schist-Limestone) Group.*—This group is one of the most important stratigraphical divisions of the Highland Schists of this section. Its main rock types are black schist and limestone; stratigraphical groups characterised by these two rock types are known throughout the Highlands. On the coast the Sandend Group forms the shores of Sandend Bay and follows evenly from the Garron Point Group, but is faulted against the succeeding group on the east, that of the Durn Hill Quartzite. This fault runs N.W.–S.E., and a short distance inland what may be taken to be the full succession of the Sandend Group is found. The width of the fullest outcrop across strike is a little more than a mile; the dip is uniformly S.E. at angles of 66° to 80°. In the fullest succession there are seven broad belts of limestone, but whether these are distinct limestones or repetitions of one or more is not yet settled. A summary of the succession from the margin of the Garron Point Group eastwards is as follows :—(i) crushed good black schist with white limestone lenticles, 5 yds.; (ii) thick limestone, 17 yds.; (iii) calcareous flags, black schists, actinolite-schists and mica-schists, 170 yds.; (iv) limestone, 17 yds.; [gap of 365 yds.]; (v) limestone, 40 yds.; (vi) black schist, 230 yds.; (vii) limestone, 60 yds.; (viii) black schist, 22 yds.; (ix) limestone, 120 yds.; (x) black schist, 2 yds.; (xi) limestone, 90 yds., faulted against Durn Hill Quartzite. To this section may be added, from inland exposures in the Burn of Fordyce, the following items :—(xii) black schist with staurolite, 372 yds.; (xiii) limestone, 150 yds.; (xiv) black schist with staurolite, 230 yds., up to the approximate edge of the Durn Hill Quartzite.

(g) *Durn Hill Quartzite.*—This group takes its name from Durn Hill, 2 miles S.W. of Portsoy; it occurs on the coast at Redhythe Point between Sandend and Portsoy. The width of its coastal outcrop across strike is perhaps a mile; dips are steep and variable; the strike varies between N.E.–S.W. and N.–S. The group is faulted, on the coast, against the Sandend Group

Digitized by Google

as has already been pointed out, but eastwards it passes into the Portsoy Group. Inland, this quartzite is at present considered to be conformable to its neighbours. The rocks of this group are more impure, more massive, less flaggy and less alternating than those forming the Cullen Quartzite already described. The most quartzose type is a felspathic quartzite composed of quartz, orthoclase, acid plagioclase and microcline, and micas. With this type are associated mica-quartz-gneisses, sillimanite-gneisses, flaggy micaceous quartzites and garnetiferous mica-schists, the last three rocks being of restricted occurrence.

(h) *Portsoy Group.*—This group occurs on both sides of Portsoy and follows on eastwards from the Durn Hill Quartzite. Its outcrop is about one mile across strike, but over half of this breadth is occupied by the sill-like mass of Older Igneous Rocks comprising serpentinised pyroxenite and peridotite, anorthosite, gabbro, enstatite-gabbro, epidiorite, amphibolite, gabbro-schist, hornblende-schist and hornblende-granulite, of which a summary has been given elsewhere.[1]

The sediments of the Portsoy Group are varied. A traverse eastwards from the east edge of the Durn Hill Quartzite shows the following succession. For 400 yds. the rocks are dark corrugated mica-schists, often silvery and garnetiferous: in this series are three narrow zones of graphite-schist. The dip hereabouts is E.S.E. or S.E. at 50°–70°. Eastwards of this belt and occupying the shore for over 100 yds. there is a very varied, rapidly alternating, group of banded calcareous flags and abundant tremolite-limestones, followed by chiastolite-staurolite-schist, dark calcareous flags, limestones and quartzose calcareous flags till the western edge of the igneous rocks is reached. Amphibolite and serpentine now form the shore for over 100 yds. Then, for about another 100 yds., a varied series of sugary white quartzite, dark mica-schist, white calcareous flags and white limestone is found before the western edge of the main mass of igneous rocks is reached. The igneous rocks form the coast about Portsoy Harbour, and include blocks of wollastonite-rock in them. The sediments, where next seen on the east shore of Links Bay, are crumpled and corrugated limy flags, impure limestones and dark mica-schists which soon pass eastwards into the next group, the Cowhythe Gneiss.

Superficially the Portsoy Group is like the Sandend Group, but when the two groups are mapped in detail, it is seen that there is really very little similarity between them.

(j) *Cowhythe Gneiss.*—This well-marked group forms the coast from Links Bay eastwards almost to the Boyne Burn. Across strike its width is a little over a mile. It follows evenly eastwards from the Portsoy Group, but is separated from the first member of the Banff Division, namely, the Boyne Limestone, by a line of

[1] H. H. Read, *Geol. Mag.*, 1919, p. 364; 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 26.

Digitized by Google

disruption which may be called the *Boyne Line*. Throughout its extent the Cowhythe Gneiss is a dark, gnarled coarse biotite-gneiss with subordinate finer mica-schist bands; throughout kernels, stringers and bands of quartz are very common. In slice, the typical gneiss is composed of quartz, acid plagioclase, biotite and muscovite, occasionally with sillimanite, cordierite and tourmaline. At a point 300 yds. from its western edge, there is a calcareous horizon with about 10 ft. of white limestone, which may be called the Rosehall Croft Limestone. At the Boyne Line, the Boyne Limestone is composed of thin limestone and purplish phyllites. As these rocks are followed in towards the margin of a nose of good Cowhythe Gneiss, they are seen to be drawn out and finally to disappear against the gneiss. All around there is much brecciation and slickensiding of the rocks. A short account of the phenomena along the Boyne Line as it is traced inland will be given in a later page.

Banff Division.

(k) *Boyne Limestone.*—Eastwards of the Boyne Line, the Boyne Limestone is seen around Craig of Boyne and Boyne Bay. From the Boyne Line eastwards for perhaps 140 yds., the rocks are thin limestones, purple phyllites and banded mica-schists with quartz kernels. Several fault breccias are seen hereabouts. Eastwards follows the thick mass of Boyne Limestone, which has a width across strike of about 300 yds. This limestone is grey, blue or white, with thin intercalations of more impure material and with nests and kernels of quartz. It is violently folded and crumpled.

(l) *Whitehills Group.*—The Boyne Limestone passes eastward into this group by the incoming of purplish phyllites and the gradual disappearance of limy bands. The Whitehills Group forms the coast for three miles, and is linked on the west to the Boyne Limestone and on the east to the Boyndie Bay Group. It is a very flaggy group made up of rapid alternations of its several members. These are banded flaggy quartzites, compact fine-grained limestones, coarse gritty limestones, calcareous flags, purplish phyllites and pebbly grits with large pebbles of quartz and pink felspar. In addition, there are a few bands of nodular andalusite-mica-schist, which become more common towards the east till the next group is reached, in which they are the predominant rock type. On the whole, it may be stated that the pebbly limestones are confined to the western and central parts of the outcrop, the coarse pebbly grits and andalusite-schists to the eastern part. On Knock Head, there is a great development of coarse pebbly grit with pebbles, occasionally composite, but more often of either quartz or pink felspar, which may reach an inch or more in diameter. Several broad sills of amphibolite are found in this group about Whyntie Head.

(m) *Boyndie Bay Group.*—This group is seen in Boyndie Bay to the west of Banff. Throughout it there occur bands of pebbly

Digitized by Google

quartz-felspar-grit like those already mentioned from the preceding group. The main rock is, however, a slaty rock, characterised by the gradual development of andalusite from a rudimentary to a complete form. The western edge of the group is characterised by silvery rocks studded with large crystals of andalusite; these are followed eastwards by rocks with elongated knots of andalusite, and these, still further east, by spotted slates which, in turn, give place to the unspotted slates of the next group. Whatever the cause of this development of andalusite, it is apparent that its effects increase in intensity from east to west.

(n) *Macduff Group*.—This great group occupies the remainder of the coast section here described, and is well exposed for a distance of 9 miles eastwards from Banff. The beds are thrown into a rapid series of steep-sided folds; but, even so, this group is probably of very great thickness. Strikes are between E.N.E.–W.S.W. and N.E.–S.W. The main rock of the group is a blue or green slate which has been worked for roofing slate at various points. With this occur in subordinate amount, pebbly quartz-felspar-grits, fine-grained grey and white grits, and fine blue greywackes.

There can be no doubt that the four members of the Banff Division form a natural stratigraphical sequence; they are linked together by transitions and by a thorough community of rock types.

It has now been shown that the Highland schists of the Banffshire coast section fall into two great divisions, separated by the line of disruption described as the Boyne Line. To the west of the Boyne Line there is the Keith Division, composed of rock types which are probably the continuation of Central Highland rocks. The Keith Division is thoroughly metamorphic in character; schists and gneisses represent the pelitic facies of the original sediments; chief among the metamorphic minerals are garnet, staurolite, kyanite and sillimanite. Eastwards of the Boyne Line is the Banff Division of which a few types recall some of those of the Loch Awe district of the S.W. Highlands. This division is much less highly metamorphosed; phyllites, rather than mica-schists, predominate in the more highly-metamorphosed parts; slates and clastic sediments are widespread; andalusite is the characteristic metamorphic mineral of this division.

If the ideas of metamorphic zones conditioned by depth of burial, advanced by C. Van Hise, F. Becke, U. Grubenmann and others, are to be accepted, then it follows that the Banff Division is structurally above the Keith Division. Further, the Macduff slates must be structurally the highest member of the Banff Division.

The phenomena along what may be considered the inland extension of the Boyne Line are not without interest. The thick

Digitized by Google

Boyne Limestone (the thickest limestone of this section) can be followed southwards for less than 2 miles. Southwards, again, the Cowhythe Gneiss is adjacent to the Whitehills Group. Still further south, both the Cowhythe Gneiss and the Whitehills Group vanish, and in the ground to the S.W. of Huntly the Portsoy Group comes against the pebbly grits and andalusite-schists of the Boyndie Bay Group. It seems possible, therefore, that this line of disruption that has been found at the Boyne on the coast may be an important tectonic feature in the architecture of the Highland Schists of N.E. Scotland. The complete elucidation of the Boyne Line can only be obtained by the detailed study of the Buchan, Formartine, Alford and Strathdon districts of Aberdeenshire—a study which has not yet been attempted.

The Banffshire Coast Section in relation to the Highland schists of other parts of Scotland.—The chief point of interest following from this study of the Banffshire rocks seems to be their separation into two divisions. There appears to be little doubt that one of these—the *Keith Division*—represents the northern continuation of the Perthshire Schists described by Mr. George Barrow, Mr. Cunningham Craig and others, in the Memoirs on Sheets 55, 65 and 64. There seem to be very large questions still to be settled in the Perthshire ground and, until some agreement has been reached as to the stratigraphical sequence in this area, it is a hazardous proceeding to attempt any thorough correlation.

It has been shown that, in Banffshire, there are two quartzites, of which one, the Cullen Quartzite, contains rock types in a Moine state. The Cullen Quartzite is undoubtedly that seen at Ben Aigan on Speyside (Sheet 85), and the Ben Aigan Quartzite appears to be continued south by a belt of quartzite at the edge of the Moines to Inchrory in Sheet 75. South of this, the cordon of the Cairngorm, Lochnagar and Hill of Fare Granites sweeps right across the path of the Keith Division. Two quartzites, so far as I know, have not been recognised in Perthshire. There is every reason to believe that the second Banffshire Quartzite, that of the Durn Hill, is the Central Highland Quartzite of Perthshire. I hold, at present, that the Durn Hill Quartzite is conformable to its neighbours and is interstratified in the Keith Division. The relations of the Central Highland Quartzite in Perthshire are the subject of dispute.

Another fairly sure step may be made. The Sandend (Black Schist-Limestone) Group, occurring on the west side of the Durn Hill Quartzite, appears to be equivalent to the Blair Atholl (Black Schist-Limestone) Group occurring on the west side of the Central Highland Quartzite. Lithologically they are the same.

The Findlater Flags, Crathie Point Group and Garron Point Group resemble the Parallel Banded Series (Hones) and Tremolite-

Digitized by Google

Limestone of Perthshire, and it is possible that this correlation will hold.

It has been shown that, in Banffshire, the rocks on the opposite sides of the Durn Hill Quartzite are, while somewhat similar, two distinct rock groups, those of Sandend and Portsoy. From what can be made out of the complicated and, in part, controversial description of the Perthshire ground, it appears that this independence of the two 'dark schist and limestone' groups on opposite sides of the Central Highland Quartzite has not always been recognised. In agreement, I believe, with Mr. George Barrow, I am inclined to correlate, after a short visit to the Perthshire ground, the Portsoy Group with the zone of thin limestone and dark schist seen on the south-east side of the Central Highland Quartzite on Farragon Hill and Beinn Eagach, and beside the Tummel opposite Faskally House. In the published map of this ground (Sheet 55), this Beinn Eagach group is shown as running into the Blair Atholl group on Meall Uaine, north of Pitlochry. This, from my Banffshire experience, I consider to be extremely unlikely.

To the south-east of the Beinn Eagach Group of Perthshire, there occur the Ben Lawers Schists (= Calc-sericite of Central Perthshire = Caenlochan Schists of Forfarshire, *fide* Mr. G. Barrow). These are possibly represented in Banffshire by the Cowhythe Gneiss.

No representative of the Schichallion Boulder Bed has yet been found in Lower Banffshire. It is known in Upper Banffshire at Meikle Fergie Burn, opposite Gaulrig, south of Tomintoul.

The following table of quite tentative correlations may be constructed :—

Banffshire.	Perthshire.
—	Loch Tay Limestone
—	Garnetiferous Mica-Schist
Cowhythe Gneiss	Ben Lawers Schists
Portsoy Group	Beinn Eagach Group
Durn Hill Quartzite	Central Highland Quartzite
Sandend Group	Blair Atholl Group
Garron Point Group, Crathie Point Group	Tremolite-Limestone
Findlater Flags	Parallel Banded Rocks or Hones
West Sands Group	—
Cullen Quartzite	—

The *Banff Division*, with its great development of slates, pebbly grits and gritty limestones, appears to be absent in Perthshire; this division is probably confined to Lower Banffshire, Strathbogie, Cabrach, the Howe of Alford, and Buchan. A few of its rock types, notably the pebbly quartz-felspar-grits and the gritty limestones, are lithologically similar to types occurring in the Loch Awe region of the South-west Highlands. Further, the state of metamorphism is low in both areas. No

Digitized by Google

definite correlation between the Banff Division and the Loch Awe Group is advanced here; the above suggestions, however, are to be borne in mind in any further investigation of the North-East Highlands. By the development of research in the South-West Highlands, it is possible that some light will be thrown on the problems of the Banff Division, and in particular with regard to the significance of the Boyne Line and the resemblances of this division to the Loch Awe Group.

Digitized by Google

APPENDIX II.

Report on Sections exposed in Excavations for Sewers in the Parish of Brockenhurst, Hants.

By H. J. Osborne White, F.G.S.

1. Introduction.

The construction of the Brockenhurst Sewer-System was undertaken for the Lymington Rural District Council by Messrs. Grounds and Newton, Contractors, of Richmond Chambers, Bournemouth, according to plans prepared by Messrs. Shanton and Easdale, Engineers, of No. 28, Victoria Street, Westminster.

Begun at the lower, or Disposal-Sump, end in 1914, and discontinued during the late war, the work was resumed in the autumn of 1919, and completed, as far as excavation was concerned, by the end of December, 1920. (The full drainage-scheme includes connections with Setley, Brockenhurst Weirs, and other outlying or detached settlements, but the construction of these branches has not yet been sanctioned.)

At the request of the Director of the Geological Survey (Sir Aubrey Strahan), the author of this Report made a preliminary inspection of the ground within the area of the Sewer System on the 9th–10th July 1920, and subsequently revisited Brockenhurst on eleven occasions, between the latter date and the 1st January 1921, with the object of compiling a record, and collecting specimens, of the strata exposed in the sewer-trenches opened under the then-existing contracts with the District Council. Opportunity was taken to inspect a number of pits in the Headon Beds, near Brockenhurst, all of which were found to be in worse condition than they had been six or seven years before; and a visit was paid to parts of the Barton coast-section having a direct bearing on the stratigraphy of the Sewer area.

The writer is under an obligation to Mr. W. Faber Elliot, the Resident Engineer, for ready assistance in the examination of the Sewer works and plans, as well as for periodical communications relating to the progress of the trenching and the nature of the ground in course of excavation.

2. Geological and other Formations Exposed.

Barton Sand.—To judge by their lie and character, the oldest strata trenched belong to the uppermost 20 ft. of the Becton Bunny Beds, or middle stage of the Barton Sand, as developed in the cliffs of Christchurch Bay. They consist of evenly-bedded, fine-grained, ferrous, micaceous, muddy sands; of blue-grey tint in the deeper sections and in those below local stream-level;

Digitized by Google

dark-yellow, orange, or brownish-red where weathered. Their junction with overlying permeable beds, whether of Barton or later age, is commonly marked by a band of orange coloration, which is fairly constant in width, as if pertaining to a definite stratum, where the cover is part of the Barton Series.

The succeeding Long Mead End Sands (about 15 ft. thick) also are fine-grained and micaceous, but contain much less argillaceous and ferruginous matter, and are normally loose and light-tinted; pale greys and yellows predominating. Near their upper limit, however, they become rather loamy and greenish-grey, owing to the introduction of green mud like that prevailing in the Lower Headon Beds above, and include thin seams of a more positively argillaceous nature. At the Sewage Disposal Works, by Haze Farm, a light-green loamy sand, inferred to lie immediately below the Headon Beds, contains marcasite-concretions; some of irregularly lenticular shape, following the lamination of the sand; others sub-cylindrical, and disposed at various angles thereto. The scanty and ill-preserved organic remains observed in the Barton Sand of the Sewer area occurred as casts (wood, *Cyrena sp.*, *Psammotea* ?) in the lenticular concretions.

Lower Headon Beds.—The lateral variation to which the members of this freshwater series are subject was apparent in the Brockenhurst trenches.

The well-marked bottom-bed, which rests evenly on the Barton Sand, normally consists of a few inches of black, dark-grey, or soot-coloured carbonaceous silty clay to loam; partly laminate or shaly; partly (where the silt element predominates) of confused, flocculate structure. When weathered, it assumes the colour and appearance of moulded chocolate, and, in the majority of the trench-exposures, this facies only was presented. In at least two sections of the Headon-Barton contact, in the southern part of the Sewer area, the bed in question was missing.

In the neighbourhood of the Railway Station, the bottom-bed is succeeded by a white to pale greyish and greenish clayey silt, mottled rusty-brown, and resembling marl, but free from calcium carbonate. Similar deposits occur at the same horizon at and about the Disposal Works, half a mile to the north-east, and at Lymington, 4 miles to the south. In the southern part of the Sewer area, however, a bright-green clay with red mottling takes the place of the pale silt, which is either absent from the lower portion of the Headon succession, or—as in one observed instance—is developed at a slightly higher horizon.

Next follows light-green to greyish-green tough clay; pure, or with silty inclusions, in the lower part, and becoming arenaceous upward through the introduction of fine white quartz-sand, which occurs chiefly in little nests and thin partings. The succeeding beds of this Series, as far as seen, are light-greenish and greyish distinctly-sandy clays and clayey-sands.

No fossils could be found, either in the trenches or on the rain-washed heaps of excavated material. Save for a little

Digitized by Google

granular race, the visible parts of the beds had been decalcified. The maximum thickness of Headon Beds exposed was about 20 ft. It was hoped that the interesting basal ('Brockenhurst') beds of the Middle Headon, which approach to within that number of feet of the Barton Sand under Ladycross Lodge, 2 miles eastward, would be encountered in the trenches near the Railway, but nothing resembling them, or suggesting deposition under marine conditions, was forthcoming.

Valley Gravel.—The bulk of this is typical river-gravel, of fine to medium texture, sandy, clearly stratified and current-bedded. Approximately 99 per cent. of the stones are sub-angular flints; the residue is made up of flint pebbles, sub-angular Selbornian cherty sandstone, pebbles of vein-quartz, &c., all most probably derived from the Plateau Gravel of the basin of Lymington River. The sand mingled with the stones, and occurring separately in seams and lenticular banks intercalated in the gravel, is mostly of light tints, and resembles that of the highest beds of the Barton Sand. In places, beds of reconstructed dark bluish-grey (Becton Bunny) sand were met with, one of which (at Waters Green) contains remains of plants. Masses of green clay and pale silt detached from the Headon Beds are not uncommon near the boundary of that formation. Cementation of the gravel, by iron peroxide and calcareous tufa, occurs sporadically and on a small scale. The greater part of the Valley Gravel within the Sewer area is disposed in gently-inclined sheets, rising from beneath the Recent Alluvium to a height of about 20 ft. above the neighbouring streams.

Trail.—In many places the Tertiary formations and the Valley Gravel are covered by from 1 to 5 ft. of stony or gravelly loam and sandy clay, largely composed, and containing incompletely assimilated bodies, of Headon clay and sand, Barton sand, and Plateau or Valley gravel; and commonly possessing a rude flow-structure, which was well displayed in the wet, clean-cut sides of the sewer-trenches. The bottom of the deposit is markedly uneven, especially on sand and gravel, into which it descends in vertical and oblique pockets. While this pocketing —and the contortion-phenomena often associated with it—may be due in a great measure to repeated intrusion, expansion and decay of tree-roots under present-day conditions, the trail itself is most probably the outcome of exceptionally active solifluction, under bygone conditions inimical to forest vegetation.

By the progressive blending of its varied constituents, the trail passes into impure brickearth. About Brockenhurst the trail is of no little importance agriculturally, inasmuch as it masks a good deal of stiff Headon clay, and affords a retentive soil for grass and arable-land over tracts of normally barren sand and gravel.

Alluvium.—This comprises peat, sandy flood-loam (brown and of open texture near the surface; greyish and more compact below), and parts of the low-level Valley Gravel rearranged by

Digitized by Google

the streams in Recent times. Thin peat and peaty earth or sand, occupying slight hollows in the flood-loam and Valley Gravel, were intersected by the trenches at Culverley Green and south-west of Brockenhurst Bridge. In the first-named locality, sand and gravel, containing much peaty matter and drift-wood were met with a few feet beneath the bed of the brook.

Made Ground.—Except in the railway-embankments and causeways, and above culverts and water-mains, the made ground cut by the sewer-trenches was of moderate or trifling thickness, and generally consisted of road-metalling. The writer neither saw, nor could hear of the discovery of, any objects of archaeological interest. The early settlement of Brockenhurst presumably lay on the spur of comparatively high ground supporting the Parish Church, outside the area of the sewer-system.

3. Rectification of the Geological Survey Map.

The boundaries of the Solid formations and of the Valley Gravel about Brockenhurst are so obscured as to render their accurate mapping impossible, without the aid of the boring-tool, or of an adventitious series of cross-sections, such as those afforded by the main-drainage works.

At Balmer Lawn, the boundary of the Headon Beds lies a little to the west of the line assigned to it in the current Geological Survey Map on the 1-in. and 6-in. scales; while in the tract between the grounds of Careys (formerly 'Brockenhurst Lodge') and Brockenhurst Weirs, it lies in places nearly half a mile south-east of that line. In the latter area, a thin spread of trail is responsible for the misleading occurrence of soils and vegetation appropriate to the Headon Beds on a low-lying portion of the Barton Sand outcrop. The Headon Beds hereabouts come on in a slight rise, which begins to be noticeable some 150 to 200 yds. north-west of, and 10 to 15 ft. below, their boundary.

The Valley Gravel proves to extend farther southward of the Lymington River than has been supposed, and to occur in considerable thickness within a few yards of its southern limit near the middle of the village. Boundary features are faint or wanting, much of the ground having been smoothly graded before and during the formation of the trail.

Digitized by Google

APPENDIX III.

On Borings for Coal near Maryport, Cumberland.

By Bernard Smith, M.A.

Two boreholes have been put down recently, by the Cumberland Coal, Power and Chemicals, Ltd., to test the Coal Measures concealed beneath the New Red Sandstone near Maryport, on the northern side of the so-called 'Boundary Fault' of the Cumberland coalfield.

Near Maryport, at least, it was expected that higher Coal Measures would have been present than in the exposed field south of the fault; in fact, the Boundary Fault had previously been driven through in the Ten Quarters Coal at Ellenborough Colliery,[1] and Whitehaven Sandstone was said to have been entered on the north side, and to prove a great downthrow in that direction, corresponding with the downthrow observed in the Triassic Rocks.

The strata penetrated by these bores, however, did not support this view, and, moreover, did not appear to correlate with anything known in this part of the county. At the invitation of the Company the cores were first examined in detail in May 1920, and permission to publish the results has been given freely by Messrs. A. E. Barton and H. E. P. Cottrell, Directors of the Company. Our thanks are also due to Major J. G. Scoular of Oughterside Colliery, under whose supervision the borings were made.

Bank End Boring (Fig. 3).

This boring is situated close to the cemetery, 1½ miles N.N.E. of Maryport, on the west side of the road to the coast. One-in. New Series Ordnance Map, Sheet 22; Old Series Geological, 101 N.W.; 6-in. Cumb. 45 N.W. Lat. 54° 43′ 55″, Long. 3° 28′ 25″. Height of surface above O.D. 27 feet.

The boring was executed by the Sullivan Machinery Co., U.S.A. Commenced November 1919 and completed May 1920. The cores were 2-in. diam. throughout. The dip in the St. Bees Sandstone is low; in the Coal Measures it varies from about 10° to 18°, and in the Carboniferous Limestone Series from 13° in shales (1,826 ft.) to as much as 30° or 35° (1,707 ft.) in laminated sandstones.

The journal of the boring is printed in slightly condensed form as it was received from the engineers, but descriptive notes, in square brackets, have been added after examination of the cores.

---

[1] 'Final Report of Royal Commission on Coal Supplies,' 1905, pt. ix., p. 17.

Digitized by Google

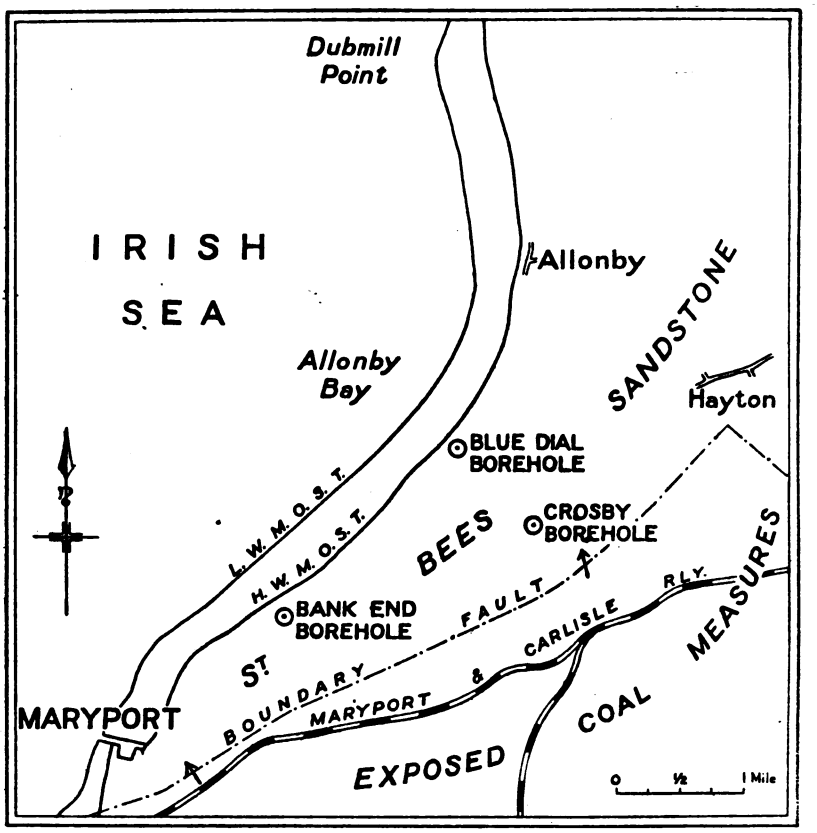

FIG. 3.—Sites of Borings near Maryport.

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL :—				
Gravel, clay and sandy clay	34	0	34	0
ST. BEES SANDSTONE :—				
Red sandstone, with bands of red marl and shale: thin bands of gypsum between 283 and 493 ft. [sandstones with greenish-grey bands at intervals: the chocolate-red shales are micaceous in places]	510	6	544	6
[Breccia] Base of sandstone with small marl pebbles, &c.; Red and green marls churned together; Fragments of Coal Measure shales, &c.	3	0	547	6
LOWER COAL MEASURES :—				
Rough red shale, variegated [purplish fine-grained shales and sandstones, with occasional concretions of hæmatite]	23	8	571	2
Very dark shale		4	571	6
BONE COAL [sandstone and coal mixed]	1	7	573	1
Grey sandy shale [with rootlets in upper part, on shales with ironstone balls]	10	11	584	0
Dark shale and metal [grey mud-stones with rootlets]	3	3	587	3

Digitized by Google

	Thickness. Ft.	in.	Depth. Ft.	in.
COAL [poor and pyritous]		7	587	10
Hard grey shale	2	2	590	0
Sandy shale	6	0	596	0
Blue metal [grey and blackish mudstone with rootlets, pinnules and shells. Ironstone at 600 ft. 1 in.]	11	0	607	0
Red and dark shale, mixed	2	0	609	0
Red and grey shale [micaceous sandstone at base: spar joints]	5	0	614	0
Red sandy shale	6	0	620	0
Dark grey shale [mudstone with rootlets]	6	0	626	0
Very dark shale [with rootlets and shells]	11	5	637	5
BONE COAL with spar [and copper-pyrites]	1	1	638	6
Hard fireclay [mudstone with rootlets]	4	6	643	0
Fireclay [fine-grained, dark grey sandstone]	1	0	644	0
Grey beds and mixed sandy shale [red and black]	23	0	667	0
Light-brown sandstone [pinkish: micaceous near base]	39	0	706	0
Dark shale with variegated sandstone bands [dark and red sandy shales, both with black mica]	13	0	719	0
Dark shale [plants and shells]	2	5	721	5
BONE COAL	1	1	722	6
Fireclay [fireclay 2 ft., on sandy shale and sandstone]	7	6	730	0
Grey sandstone	3	0	733	0
Dark shale [with plants, shells and ironstone]	24	0	757	0
Black metal [smooth black shales with fossils]	1	11	758	11
COAL [poor]	2	3	761	2
Fireclay [and sandstone]	1	10	763	0
Sandy grey shale [chiefly white sandstone]	5	0	768	0
Dark shales, with ironstone [fossils]	9	3	777	3
COAL, traces of spar and sulphur [pyrites]	1	6	778	9
Fireclay	1	3	780	0
Dark grey shale [some fireclay]	18	0	798	0
Dark shale [shale and sandstone: plants]	24	4	822	4
COAL [with 3-in. roof of black shale]		11	823	3
Fireclay	2	9	826	0
Dark shales [and shaly sandstone]		10	826	10
COAL		1	826	11
Fireclay [brown and sandy]	2	1	829	0
Dark shale and grey bed [with current-bedded sandstones, and plants]	30	0	859	0
White sandstone on dark shale [plants]	10	0	869	0
Fireclay with ironstone bands near base	4	6	873	6
Grey sandstone	25	9	899	3
Dark shale [black: ironstone balls, and fish remains]	9	3	908	6
Fireclay [pulped shale on black shale]	2	0	910	6
COAL [poor]	1	9	912	3
Fireclay	2	9	915	0
Sandy shale	16	0	931	0
Fireclay [grey shale, on 18 in. fireclay]	5	0	936	0
Sandy shale and grey bed [1 ft. fireclay: plants]	15	0	951	0
Sandy and dark shales [soft black and micaceous: shells and plants]	25	10	976	10
COAL [core missing]		5	977	3
Dark shale [plants and ironstone]	6	9	984	0

Digitized by Google

	Thickness. Ft.	in.	Depth. Ft.	in.
COAL [poor, with calcite joints]		8	984	8
Fireclay	1	4	986	0
Dark shales [mudstone with ironstone]	5	2	991	2
COAL [poor]		11	992	1
Fireclay	1	11	994	0
White sandstone	27	0	1,021	0
Fireclay and dark shale	5	0	1,026	0
CARBONIFEROUS LIMESTONE SERIES :—				
Dark shales with shells and spar bands [crinoids and marine shells]	1	0	1,027	0
Sandy shales [white sandstone with dark shale and coaly layers]	4	0	1,031	0
Dark shales	1	0	1,032	0
Hard fireclay [shaly at top]	5	0	1,037	0
Fireclay [greenish shale]	3	0	1,040	0
Dark shale [shales and mudstones; ferrous carbonate and pyrites]	10	0	1,050	0
Dark shale	10	0	1,060	0
Dark brown shale [fossiliferous]	9	0	1,069	0
Grey bed, hard post and sandstone [whitish quartzose sandstone, with black mica, and 1 foot shale]	36	0	1,105	0
Dark shale with ironstone nodules and few shells	4	0	1,109	0
Hard dark shale [fossiliferous]	16	0	1,125	0
Dark firelay [smooth micaceous shale and bastard cannel]		8	1,125	8
COAL, very dirty [full of calcite]		4	1,126	0
Fireclay	1	6	1,127	6
Very coarse grey bed [sandstone and shales]	18	6	1,146	0
Dark shale with ironstone, pyrites and crinoids, on sandstone and shale : limestone at 1,171 ft.]	30	0	1,176	0
Sandstones and sandy shales [fossiliferous]	139	0	1,315	0
Red sandstone [pink, purple and white : micaceous]	13	0	1,328	0
Fireclay [dark grey, black and purple : micaceous]	2	0	1,330	0
Grey bed [20 ft.], on sandstone	48	0	1,378	0
Dark grey sandy shales [black mica and plants]	4	0	1,382	0
Grey bed, separated by sandstone, 4 ft. [plants]	23	6	1,405	6
Black shale [shells and plants]	12	0	1,417	6
Hard dark shales [dull sandy shales, calcareous in places : highly fossiliferous. *Reddish limestone* at 1,425 feet]	44	0	1,461	6
Red, on white, sandstone [white, pink and red, micaceous and with shales]	16	6	1,478	0
Black shale [mixed with sandstone : plants]	12	0	1,490	0
Dark black, sometimes sandy, shales and grey bed [pyrites nodules and traces of plants]	35	0	1,525	0
White sandstone [purplish in places : coaly layers]	13	9	1,538	9
Dark shale with 1 in. COAL		3	1,539	0
Grey bed and white sandstone, mixed	17	9	1,556	9
COAL		6	1,557	3
Brown shale		3	1,557	6
Fireclay [black, with rootlets]	3	0	1,560	6
Sandstone and grey bed	16	6	1,577	0
Dark shales, grey beds and sandy shales [plants, crinoids and shells from 1,636–1,637 ft.]	79	0	1,656	0
White sandstone	12	0	1,668	0
Dark shale and grey bed	27	6	1,695	6
Broken dark shale [1,697–1,698 ft., dark shale on black shale with *Lingula*]	3	6	1,699	0

Digitized by Google

	Thickness. Ft.	in.	Depth. Ft.	in.
COAL—*continued.*				
Sandstones and grey beds, some red	37	0	1,736	0
Grey bed and dark shales	65	0	1,801	0
Sandstones, grey beds and shales [fossils at 1,826–7 ft.]	96	0	1,897	0
Grey and white sandstone	24	6	1,921	6
Dark shale [with sandstone: fossils at 1,954 ft. 6 in. in ferrous carbonate]	63	6	1,985	0
Grey bed, sandstone and shale with spar	14	0	1,999	0
Dark shales and sandstones, mixed	75	0	2,074	0
White sandstones and grey beds	157	0	2,231	0
COAL		4	2,231	4
Shale, sandstone and grey bed	64	8	2,296	0
COAL		4	2,296	4
Dark shale, grey beds, sandstones and shales	250	8	2,547	0
COAL		3	2,547	3
Shale and sandstone	36	3	2,583	6
COAL, small pieces	1	10	2,585	4
Sandstone, grey bed and shale	62	8	2,648	0

BLUE DIAL BORING (Fig. 3).

This boring is, in its essentials, similar to the above, but was finished at a slightly later date. It is situated close to the coast-line nearly 2 miles N.E. of the Bank End boring and about 200 yds. S.W. of Blue Dial. Six-in. Cumb. 35 S.W. Lat. 54° 45′ 9″, Long. 3° 26′ 25″.

Height of surface above O.D. 21 ft.

The dip of the lower series is in places as high as 30°.

A summary of the chief divisions is as follows :—

	Thickness. Ft.	in.	Depth. Ft.	in.
GLACIAL	46	6	46	6
ST. BEES SANDSTONE, with 3-in. breccia at base	664	6	711	0
LOWER COAL MEASURES, stained red and purple to about 880 ft., with 13 thin coals	951	0	1,662	0
CARBONIFEROUS LIMESTONE SERIES, with coal and shale parting at from 2,043 ft. 8 in. to 2,045 ft. 8 in.	673	0	2,335	0

The breccia at the base of the Trias in this boring consisted of small pellets of New Red Marl and Sandstone in sandstone, on small fragments of Coal Measure shales. There was also a thin layer of fibrous gypsum close above the breccia. The junction was difficult to detect owing to the staining of the underlying Coal Measures.

The base of the Coal Measures in each boring has been fixed at a point below which there is the first appearance of crinoidal and shell-bearing shales of marine type. Lithologically, however, apart from some thin bands of limestone, calcareous shales, or calcareous sandstone, the lower series bears a resemblance to the Coal Measures. Bands and balls of ferrous carbonate and pyrites occur in both, and certain shales and sandstones contain black mica. Plant remains also occur in both. There is no sign of unconformity at the junction in either section.

Digitized by Google

The 'grey-beds' are usually alternations or admixtures of sandstone and shale.

The Coal Measures contain no coals that can be recognised in neighbouring collieries and none appears to be of value. The coals in the underlying beds are apparently placed for the first time at their proper horizon, although they may have been bored through or may crop out in the district.

The fossils given below have been examined and named by Mr. J. Pringle and Dr. Robert Kidston, F.R.S.

LIST OF FOSSILS FROM BANK END BOREHOLE, MARYPORT, CUMBERLAND (B.S. 1439–1803).

	Depth in Feet.
Mariopteris muricata (*Schloth.*)	802–807
Neuropteris heterophylla *Brongn.*	735–744
,, *cf.* ,,	566, 570
,, tenuifolia (*Schloth.*)	818–820
,, *cf.* ,,	802–807
,, sp.	802–807, 818–820
Sphenopteris *cf.* obtusiloba *Brongn.*	802–807
Calamites sp.	735–744
Cf. Calamites carinatus *Sternb.*	,,
Asterophyllites charaeformis (*Sternb.*)	783
,, equisetiformis (*Schloth.*)	802–807, 818–82
Calamostachys sp.	818–820
Lepidophyllum sp.	958
Stigmaria ficoides (*Sternb.*)	980
Cordaites sp.	818–820
[1]Carbonicola *cf.* aquilina (*J. de C. Sow.*)	600, 630
[1] ,, sp.	571, 600–607, 631, 744–7
[1] ,, ?	744–747, 901
Crinoidal columnals	1,048, 1,068, 1,171
Fenestellid	1,062
Lingula squamiformis *Phill.*	1,697
,, *cf.* ,,	1,173
,, sp.	1,100
,, ?	977
Orbiculoidea nitida (*Phill.*)	1,428
Productus, *cf.* longispinus *J. Sow.*	1,425
,, sp.	1,425, 1,440
,, ?	1,280, 1,412
Schellwienella sp.	1,425
Cypricardella sp.	1,280
Euphemus urei ? *Flem.*	1,045
Coelacanthus sp.	571
Rhizodopsis sauroides *Will.*	571, 904
,, ,, ?	953–955
,, ?	632
Fish remains, indet.	906

[1] Freshwater shells.

Digitized by Google

Mr. Pringle states that 'the marine shells which characterise the rocks passed through between the depths of 1,045 ft. and 1,697 ft., suggest comparison of the beds with the Cefn-y-Fedw Series of Denbighshire.' The latter has been shown in recent years to belong to the Carboniferous Limestone Series. Previously it had been termed 'Millstone Grit.'

The absence in these records of the 'Millstone Grit' of the Whitehaven District, and the extraordinary difference between the Carboniferous Limestone Series in the borings, which is of northern aspect, and that developed in the above district, where by far the greater part is massive limestone, are points of great interest and of economic importance, the significance of which will be better appreciated when the systematic mapping of the area is taken in hand and the various changes followed in detail.

That these changes have taken place before the Boundary Fault is reached from the south is proved by a boring recently sunk by the same Company at Hayborough, about 1 mile east of Ellenborough, in which strata of the Upper Carboniferous Limestone types met with at Bank End and Blue Dial crop out beneath the Glacial beds. Again strata of this lithological character, containing a thin limestone with *Schellwienella*, are exposed in two dingles ½ mile S.E. of Rosegill, and about 3½ miles east of Maryport.

A further point of interest is that the borings tend to prove that there must have been a downthrow (or steep turn-over) south-eastward along, or near the line of, the Boundary Fault, before the date of the Triassic overlap and the later northward downthrow. The supposed Whitehaven Sandstone met with in the above-mentioned driving through the fault, from the Ten Quarters Coal at Ellenborough, may well have been some of the sandstones of the Lower Coal Measures or Upper Limestone Series coloured by Triassic infiltrations.

The Crosby borehole[1] (Fig. 3) appears to have proved a sequence similar to that of the two borings under consideration, but in the absence of fossil evidence it is impossible to say exactly at what depth the Carboniferous Limestone Series was first reached—probably at much shallower depth than 1,046 ft. 9 in. which marks the top of a 33 ft. 3 in. bed of limestone. It appears, therefore, that, in the absence of faults, the base of the Coal Measures of this area strikes more or less parallel to the Boundary Fault and may dip seawards at something like 1,300 ft. per mile—an average dip of from 13° to 14°, which corresponds fairly well with the actual dips observed in the cores. The generally higher dip in the lower series is suggestive of unconformity.

---

[1] *Ibid.*

Digitized by Google

APPENDIX IV.

On a Boring for Coal at Yate, Gloucestershire.

By J. Pringle.

This borehole is situated in a field on the north side of the Bristol road 400 yds. west of Yate Station,[1] at a surface level of 225 ft. above O.D. The operations, which were carried out by Messrs. Vivian's Boring and Exploration Company, Limited, under the management of Mr. Fisher Ray, were begun in August 1918, and were completed in July 1920, after a depth of 2,203 ft. had been reached. The object of the boring was to ascertain the character of the Lower Coal Series present in the eastern limb of the synclinal fold that forms the northern point of the Bristol coalfield. An almost continuous series of cores was obtained by drilling from the surface down to the bottom of the borehole; and through the kindness of Mr. R. M. Dillwyn of Bridgend, Glamorgan, permission was granted to the Geological Survey to examine the rocks thus displayed. A series of rock-samples and fossils was collected, and these are now included in the Survey Collections at Jermyn Street.

The following is an abstract section of the borehole :—

	Thickness. Ft.	in.	Depth. Ft.	in.
Soil and rubble	2	9	2	9
Coal Measures—				
Pennant Series :—				
Grey pennant sandstone with beds of grey sandy shale and a seam of fireclay. Sandstones contain many films of coal, ironstone-nodules, and a few pebbles of coal	853	5	856	2
Soft coal		2	856	4
Strong grey fireclay and grey sandy shale with ironstone	31	5	887	9
Coarse grey conglomerate with many large sub-angular pebbles of quartzite, &c.	4	9	892	6
Bluish-grey and red marls	41	3	933	9
Coarse grey conglomerate, as above	10	9	944	6
Bluish-grey and red marls	6	0	950	6
Grey shaly sandstone	5	3	955	9
Grey conglomerate with many large pebbles	28	7	984	4
Grey pennant sandstone with bands of shale and conglomerate. Joint planes lined with calcite	74	6	1,058	10
Lower Coal Series :—				
Bluish-grey and red marls	8	8	1,067	6
Grey quartzose sandstone	1	9	1,069	3
Bluish-grey sandy shale	19	9	1,089	0
Fine grey sandstone with courses of conglomerate	1	6	1,090	6
Grey and red sandy shale	5	3	1,095	9
Grey shale	35	0	1,130	9

[1] New Series 1-in. Ordnance Map, Sheet 251 (Malmesbury); 6-in. map Gloucestershire 69 S.W.; Old Series 1-in. Geological Map 35, Lat. 51° 32′ 24″, Long. 2° 26′ 12″.

Digitized by Google

Coal—*continued.*	Thickness.		Depth.	
Lower Coal Series—continued.	Ft.	in.	Ft.	in.
Grey sandstone with bands of shale and conglomerate	6	3	1,137	0
Coal		9	1,137	9
Fireclay, sandy shale, and sandstone	20	7	1,158	4
Grey shale	17	0	1,175	4
Coal		2	1,175	6
Fireclay	11	9	1,187	3
Grey shale with a band of grey sandstone, 6 ft. thick, between 1,205 ft. and 1,211 ft. *Marine Band* at 1,227 ft.	68	3	1,255	6
Black shale	3	0	1,258	6
Coal	1	9	1,260	3
Grey fireclay and shale	12	0	1,272	3
Dark-grey and red mottled marl	5	0	1,277	3
Grey shale	18	3	1,295	6
Coal		3	1,295	9
Red and grey mottled marl	53	0	1,348	9
Grey shale	36	3	1,385	0
Coal, soft		3	1,385	3
Grey shale	107	0	1,492	3
Grey sandstone	16	5	1,508	8
Grey shale, numerous plant remains throughout	19	1	1,527	9
Coal, soft	1	6	1,529	3
Coal, soft, and black shale, mixed	1	10	1,531	1
Coal, soft	2	6	1,533	7
Dark shale		10	1,534	5
Dark shale and coal with numerous poorly preserved plants	1	0	1,535	5
Dark grey shale	29	1	1,564	6
Coal	1	0	1,565	6
Grey shale and shaly sandstone. *Marine Band* at 1,610–1,616 ft.	67	3	1,632	9
Red and bluish grey marl	19	3	1,652	0
Dark-grey shale	3	0	1,655	0
Coal		4	1,655	4
Grey shale	37	3	1,692	7
Grey sandstone	6	0	1,698	7
Grey shale	82	9	1,781	4
Grey fireclay	2	0	1,783	4
Grey sandy shale	8	3	1,791	7
Grey sandstone	1	9	1,793	4
Grey sandy shale with numerous plant remains	19	10	1,813	2
Coal	2	0	1,815	2
Dark-grey shale and fireclay	10	6	1,825	8
Grey sandstone	1	10	1,827	6
Grey shale with band of ironstone	27	7	1,855	1
Grey fireclay	1	8	1,856	9
Coal, soft		8	1,857	5
Grey shale with band of ironstone	39	2	1,896	7
Coal, soft	1	2	1,897	9
Dark shale and fireclay	33	7	1,931	4
Grey sandstone		10	1,932	2
Dark-grey shale	3	9	1,935	11
Coal, soft		9	1,936	8
Dark shale	1	6	1,938	2
Coal, soft		8	1,938	10
Dark shale	2	0	1,940	10
Coal, soft		9	1,941	7
Dark shale		9	1,942	4

Digitized by Google

Coal—*continued.* *Lower Coal Series*—continued.	Thickness. Ft.	in.	Depth. Ft.	in.
Coal	3	2	1,945	6
Grey shale and sandstone	19	4	1,964	10
Coal	1	4	1,966	2
Grey shale, fireclay, and sandstone	49	5	2,015	7
Coal	4	0	2,019	7
Black shale		5	2,020	0
Coal	1	0	2,021	0
Dark shale	2	4	2,023	4
Fireclay	4	0	2,027	4
Grey shale	13	3	2,040	7
Coal		3	2,040	10
Fireclay, shale, and sandstone	32	0	2,072	10
Grey shale with band of ironstone	38	1	2,110	11
Coal, soft	1	2	2,112	1
Dark-grey shale with band of ironstone	91	3	2,203	4

The dip of the beds, taken at various intervals, appeared to range between 10° and 35°. The rock-sequence displayed in the cores is generally similar to that passed through at Winterbourne,[1] in the western part of the coalfield; but some minor differences were noted. The base of the Pennant Series has been drawn at the depth of 1,058 ft. 10 in., and its position in relation to the highest marine band is nearly the same as in the two corresponding levels at Winterbourne. Beds of coarse conglomerate form a characteristic feature in the lower part of the Pennant Series, although similar but thinner and less coarse pebbly bands occur also in the upper portion of the Lower Coal Series. Many of the pebbles are of large size, one, a grey quartzite from 980 ft., measuring 5 in. in length; and in appearance the conglomerates are identical with those passed through at Winterbourne. Dr. H. H. Thomas, who has examined the specimens, reports that the pebbles are for the most part fine-textured rocks, variously coloured green, grey, and pink, embedded in a matrix which is highly felspathic and quartzose, much of the quartz being opalescent. The chief rock-types are quartzites, rhyolites, and vein-quartz, and, excepting a specimen of a fine-grained brownish sandstone, possibly of Carboniferous age, the whole assemblage, which is seemingly identical with that found at Winterbourne, again suggests derivation from rocks of Pre-Cambrian formations. No pebbles of the older Palæozoic sediments were recognised. The majority of the pebbles are sub-angular, and their marked increase in size, as compared with the constituents of the Winterbourne conglomerates, suggests that the source of the material lay somewhere east or north-east of the coalfield, and may indicate the presence of a buried ridge of Pre-Cambrian rocks in that direction.

In the Lower Coal Series beds of sandstone resembling Pennant rock are present, but they are subordinate to the argillaceous sediments, which are chiefly of the mudstone type.

[1] T. C. Cantrill and B. Smith, 'On a Boring for Coal at Winterbourne, Gloucestershire,' 'Summary of Progress for 1918' (*Mem. Geol. Surv.*) 1919, pp. 53–57.

Digitized by Google

The lower shales are remarkably slicken-sided. Most of the coals are soft and thin, and are frequently interbedded with shale. A seam of good quality, 4 ft. thick, was passed through between the depths of 2,015 ft. 7 in. and 2,019 ft. 7 in. It is separated from a lower coal, 1 ft. thick, by 5 in. of black shale. Two marine bands were detected in the measures. At 1,227 ft. fragments of *Lingula* were found in association with numerous shells of *Orbiculoidea nitida* (Phill.); and between the depths of 1,610 and 1,616 ft. the shales yielded several finely ribbed specimens of *Productus*. These marine bands appear to represent similar horizons passed through at the depths of 1,090 and 1,488–1,494 ft. in the Winterbourne boring. Some of the shales were found to be crowded with plant-remains, but considerable thicknesses yielded no fossils. The identification of the plants by Dr. R. Kidston F.R.S. is as follows :—

	Depth in Feet.
Alloiopteris (Corynepteris ?) coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua *Bunbury*	1,171
Lonchopteris bricei *Brongn.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697, 1,711, 1,719
Pecopteris (Dactylotheca ?) sp.	1,697
,, sp.	1,562
Sphenopteris *cf.* artemisiæfolioides *Crepin*	1,525
,, obtusiloba *Brongn.*	1,711
,, sp.	1804–1810
Calamites cisti *Brongn.*	,,
,, sp.	,,
Annularia microphylla *Sauveur*	1909
Asterophyllites equisetiformis *Schloth.*	1,525
Palæostachya sp.	1,973
Lepidophyllum lanceolatum *L. & H.*	1,711
Sigillaria mammillaris *Brongn.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1810

Digitized by Google

APPENDIX V.

Total Quantity of Tin, Copper, and other Minerals produced in Devonshire, particularly with regard to the Amounts raised from each Parish.[1]

By Donald A. MacAlister, A.R.S.M.

Many of the mines of Devon, like a still greater number in Cornwall, have long since been abandoned, and the topographical positions of such as are mentioned in records have only been determined after laborious examination of hundreds of old mine-plans preserved in local estate offices and institutions; in the Office of Woods and Forests, the Home Office, the Duchy Office and the Geological Survey, as well as a number in private ownership. It was only by this means that the recorded output of minerals could be classified according to parishes.

The tabulation of the production according to parishes presents a shorter and more rational account of the economic value of a mineral tract of country than could be obtained by a detailed list of outputs from the individual mines.

The totals from each parish during the periods are computed from the separate returns of the mines in them, as derived from the various sources mentioned on p. 274 of the *Geology of Falmouth and Truro*. As it was not until 1882 that continuous and reliable returns were published, it is likely that the details of the Tables fall short of the true amounts raised in the periods covered, and the reservations stated in the *Summary of Progress* referred to, as well as those in the memoir last cited (p. 274) must be borne in mind when considering the value of any mineral area. It will be recognised that although the records of early production are fragmentary there is enough evidence of different kinds to show that several of the ores have been worked from time to time for centuries past, and that it is impossible to embody such information in the Tables.

Mr. Lewis[2] states that the statistics of the production of tin from Cornwall and Devon in the late 12th century are not plentiful and relate mostly to Devonshire. From his perusal of the pipe-rolls Mr. Lewis was able to draw up tables of annual returns in which, however, there are many lacunæ amounting in the aggregate to several hundred years. The value of any attempt to estimate the quantities produced in the missing

[1] For the output from the parishes of Cornwall *see* 'Summary of Progress of the Geological Survey of Great Britain for 1906' (*Mem. Geol. Surv.*), Appendix II, 1907, p. 132.

[2] '*The Stannaries*', 1908.

Digitized by Google

years would, at best, be doubtful, as even if the existing records were reliable, we should still have to assess the effect on production due to wars and social conditions, in addition to the usual uncertain elements in mining and trade. It may be noted, however, that from the 13th century to the middle of the 18th century many tens of thousands of tons of metallic tin were produced from the West Country.

With regard to copper it is quite certain that the ore was raised concurrently with tin-ore from the earliest historical times; but Lysons states[1] that in 1811 only seven mines in Devon were yielding copper, and that in that year the production was as follows:—Wheal Friendship, 110 tons; Wheal Crebor, 1,308 tons; Crowndale, 863 tons; East Crowndale, 913 tons; Wheal Hockworthy, 10 tons.

The early official statistics are far from satisfactory, and although care has been taken in the Tables which follow to present a true account in accordance with available data, the amounts here given should be regarded merely as useful guides to the relative importance of the mineral areas.

We may briefly recall the fact that the available records contain many lacunæ and probably mistakes,[2] so that although we know the sources we do not know the precise extent of the errors likely to be present. The observations contained in Appendix II. of the *Summary of Progress* already referred to apply with equal force to the mineral output of Devon and need not be repeated.

The periods covered by the Tables are necessarily restricted to the 19th and 20th century, as earlier records are scarce and discontinuous.

The principal production of lead ore was in the forties and fifties of the 19th century, though it continued to be raised until the eighties; the silver was obtained mainly from the lead. We recall, however, the historical fact that the silver-lead mines of Devonshire were worked at least as far back as the 13th century.[3] Manganese was actively mined in the seventies, but we note that considerable quantities of this ore, as well as iron ore, were raised in the 18th as well as the early part of the 19th century.[4] Zinc ore was raised mainly in the fifties and sixties. The output of tin ore, as expressed in the Tables, is limited to that since 1852; of copper ore since 1821; of lead ore since 1845; of silver since 1852, and of miscellaneous minerals since 1853.

---

[1] *Mag. Britt.*, Devon, p. cclxxxiii.

[2] Such as those due to confusion between the natural and dressed ores and the metal, as well as to false returns.

[3] *See* 'Geology of Cornwall, Devon and West Somerset' (*Mem. Geol. Surv.*), pp. 611, 612.

[4] *Op. cit.*, pp. 610, 617.

Digitized by Google

TABLE I.—*Output of Tin and Copper from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Tin Ore produced from* 1852 *to* 1913; *and the Copper Ore from* 1821 *to* 1913.

Parish.	Black Tin.	Copper Ore.	Copper.[1]	Parish.	Black Tin.	Copper Ore.	Copper.
	Tons	Tons.	Tons.		Tons	Tons.	Tons.
Ashburton -	804	421	17	Molland - -	—	1,180	75
Beer Ferris -	10	205	13	North Bovey -	1,314	—	—
Belstone -	1	4,036[2]	375	North Molton	—	4,515	638
Bovey Tracey	—	2,300	86	Okehampton -	—	2,656	186
Buckfastleigh -	—	29,680	1,965	Peter Tavy, *see* Mary Tavy.	—	—	—
Buckland Monachorum	12	24,250	1,400	Plympton St. Mary - -	1,300	240	12
Chagford - -	60	—	—	South Tawton	—	6,285	344
Dartington -	56	—	—	Sydenham Damerel -	—	80	5
Holne - -	6	—	—	Tavistock -	300	933,210	59,682[3]
Ilsington -	91	—	—	Walkhampton	220	280	21
Lamerton -	61	22,600	1,285	Whitchurch -	515	20,630	1,538
Lydford - -	295	—	—	Miscellaneous -	10	1,150	80
Manaton -	203	—	—				
Mary Tavy -	408	43,250	4,015				
Meavy - -	400	—	—				

[1] Obtained from the copper ore mentioned in the previous column.
[2] Over 1,000 tons contained about 9 per cent. copper.
[3] In addition, about 90 tons of 'precipitated copper' yielding 70 per cent. of the metal.

Digitized by Google

TABLE II.—*Output of Minerals, other than Tin and Copper, from the Mines of Devonshire, grouped according to the Parishes in which they occur. The Lead Ore raised since* 1845; *the Silver since* 1852; *and the Miscellaneous Minerals since* 1853; *to* 1913.

Parish.	Lead Ore.	Lead.[1]	Silver.[2]	Pyrites (Iron and Arsenical).	Arsenic[3] Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Ashburton - -	—	—	—	720	903	22,060	The pyrites mostly arsenical. The iron oxides are 'Brown Hæmatite,' ochre and umber. Of this, 12,820 tons of ochre and umber were returned from 'Roborough' and 'Devon and Cornwall' Mines, and some from 'S. Devon Mine,' which also returned 690 tons 'spathic iron.'
Beer Ferris - -	25,670	16,324	534,010	20	—	—	The pyrites non-arsenical. Also 3,240 tons of fluor-spar.
Belstone - - -	—	—	—	102	21	—	Of the pyrites, 72 tons were arsenical.
Bovey Tracey - -	—	—	—	—	—	2,878	Of which 1,060 tons 'micaceous' iron ore, 123 tons ochre and 667 tons 'Brown Hæmatite.'
Bratton Fleming -	—	—	—	—	—	20	Red Hæmatite. Also 10 tons of manganese ore, part of which came from Sherwell Parish, *q.v.*
Brentor - - -	—	—	—	—	—	155	Ochre. Also 3,610 tons of manganese ore.
Bridford - - -	—	—	—	—	—	—	21,250 (?) tons of barytes.
Brixham - - -	—	—	—	—	—	196,311	Mainly 'Brown Hæmatite,' containing up to 50 per cent. iron. Some micaceous and some sold as ochre and 'Wolston's iron paint.'

[1] From the lead ore. [2] From the lead. [3] In addition to the arsenical pyrites.

Digitized by Google

TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
Buckfastleigh - -	—	—	—	350	—	—	Of which a proportion was arsenical.
Buckland Monachorum	—	—	—	7,575	1,715	—	Pyrites mainly arsenical.
Budeaux - - -	62	36	1,436	—	—	—	
Challacombe - -	—	—	—	—	—	50	'Brown Hæmatite.'
Chevelstone - -	—	—	—	—	—	300	'Brown Hæmatite.'
Christow - - -	26,550	17,506	367,230	—	—	689	Of the iron oxides, 48 tons were ochre and umber; 240 tons 'Brown Hæmatite,' and 182 tons 'spathic iron ore' (*see* Lustleigh). In addition, 180 tons of fluor-spar and 1,635 tons of zinc-ore.
Combe Martin - -	860	545	812	—	—	1,340	Of the iron ore, 450 tons were 'Brown Hæmatite,' and 890 tons 'umber.' In addition, 1,590 tons of 'spathic iron ore.'
Coryton - - -	—	—	—	—	—	—	*See* Milton Abbot.
Georgeham - -	—	—	—	—	—	780	'Brown Hæmatite.'
Harford - - -	—	—	—	—	—	900	'Brown Hæmatite.'
Hennock - - -	800	550	1,190	—	—	1,935	The oxide of iron was 'micaceous iron ore.' In addition, 1,200 tons of manganese ore.
Ilsington - - -	93	60	80	—	—	46,512	Of the iron oxides, 21,928 were magnetite, 16,209 'Brown Hæmatite,' 5,717 mixed 'Brown Hæmatite' and micaceous iron ore ('shining ore'), containing up to 57·5 per cent. of iron, 708 tons of ochre, 340 tons of umber, 220 tons of so-called 'Wolston's iron paint.' In addition, 1,474 tons of zinc-ore.

Digitized by Google

Kingsbridge	—	—	—	—	—	54	'Brown Hæmatite.'
Lamerton	62	39	2,915	1,410	1,011	—	Of the pyrites, 350 tons were arsenical. In addition, 602 tons of zinc ore and 77 tons of manganese ore.
Lew Trenchard	—	—	—	—	—	—	156 tons of Manganese ore. *See also* Marystow and Milton Abbot.
Lustleigh	—	—	—	—	—	1,580	Part of this from Bovey Tracey and Shuttamoor in Christow; 342 tons were 'Brown Hæmatite,' and the rest 'shining ore.'
Lydford	12	8	—	—	—	—	
Marlborough	—	—	—	—	—	100	
Marystow	—	—	—	—	—	—	1,820 tons of manganese ore, but this includes some from Milton Abbot, Lew Trenchard, Cardwell and St. Stephen.
Mary Tavy	2,000	1,176	9,150	17,875	7,685	—	Of the pyrites, 10,508 were arsenical. In addition, 160 tons of zinc ore. 'Scheelite,' and 1 ton of Wolfram from Wheal Friendship.
Milton Abbot	—	—	—	—	—	—	49,890 tons of manganese ore, but part of this came from Lifton, Sydenham Damerel, Lew Trenchard and Coryton. *See also* Marystow.
Molland	—	—	—	—	—	28,560	'Brown Hæmatite.'
North Bovey	—	—	—	—	—	25	Specular iron or 'shining ore.'
North Molton	25	9	—	150	—	17,081	Of the iron oxides, 14,181 tons were 'Red Oxide,' and 2,900 'Brown Hæmatite.' In addition, 9,625 tons of 'spathose iron' and 86 tons of manganese ore. The pyrites was non-arsenical.
Newton Abbot	—	—	—	—	—	—	40 tons of manganese ore.
Newton St. Cyres	—	—	—	—	—	—	1,401 tons of manganese ore.
Peter Tavy	—	—	—	—	—	—	*See* Mary Tavy.
Plympton St. Mary	771	367	12,050	911	270	—	Of the pyrites, 210 tons were arsenical. In addition, 8 tons of zinc ore.
Rattery	—	—	—	—	—	4,400	'Brown Hæmatite.'

Digitized by Google

TABLE II.—*continued.*

Parish.	Lead Ore.	Lead.	Silver.	Pyrites (Iron and Arsenical).	Arsenic Soot (and White).	Iron Oxides.	Miscellaneous Minerals.
	Tons.	Tons.	Ozs.	Tons.	Tons.	Tons.	
St. Stephen - -	—	—	—	—	—	—	Manganese, *see* Marystow.
Shaugh Prior - -	—	—	—	—	—	5,317	Mainly 'Brown Hæmatite,' 250 tons were 'Red Hæmatite.'
Sherwell - -	—	—	—	—	—	535	'Brown Hæmatite.' In addition, 55 tons manganese ore, *see* Bratton Fleming.
South Molton - -	80	60	64	—	—	—	
Stoke Gabriel - -	—	—	—	—	—	4,790	'Brown Hæmatite.'
Sydenham Damerel -	100	69	947	—	—	—	140 tons Zinc ore. For Manganese, *see* Milton Abbot.
Tavistock - - -	1,300	931	13,144	72,001	86,460	4,290	Of the pyrites, 50,393 tons were arsenical and 3,823 mixed 'crude arsenic and arsenical pyrites.' Oxides of iron as ochre and umber. In addition, 30 tons of wolfram and 60 tons of fluor-spar.
Ugborough - -	285	171	2,688	—	—	2,432	Of the iron oxide, 2,233 tons were 'Brown Hæmatite' and 199 tons ochre.
Walkhampton - -	—	—	—	—	2	—	
Whitchurch - -	12	7	—	152	—	—	Of the pyrites, 33 tons arsenical.
Wolborough - -	—	—	—	—	—	1,240	'Brown Hæmatite.'
Yealmpton - -	—	—	—	—	—	250	'Brown Hæmatite.'
Miscellaneous (unclassified) - -	740	565	2,575	—	—	—	160 tons of Manganese ore from 'Rostidyon' and 'Fullabrook.' 640 tons of iron ore from 'Furgam Mill' (? Brixham). The lead-ore is from 'Park,' 'South Maex,' 'True Blue,' 'Thomas United' and 'New Devon Consols.'

Digitized by Google

INDEX.

A.

Achany Lodge, 45.
Acheille, 46.
A' Chrannag, Ulva, 42.
Ach'uaine, 46.
Acton Reynald, 25, 26, 28.
Aigburth, 23.
Aird na h-Iolaire, 35.
Airth, 49.
Alford, 78.
Alloa coalfield, 4, 50, 52.
Allt Airidh nan Caisteal, 39.
—— na Feith Moire, 47.
—— — h'Atha, 47.
—— — Teangaidh, 35, 37.
Alva, 50.
Amwell, Great, 6, 7.
———— Little, 6, 7.
Anderson, E. M., 3, 31, 38, 41, 43, 48.
Andrews, C. W., 64.
Anglesey, 69.
Antimony ores report, 69.
Apedale, 30.
Applecross, 69.
Aqualate Park, 20.
Archæan rocks, 3, 31–34, 44–46, 70–80.
Ardnamurchan, 4, 36, 42.
Ardtun, 38.
Arsenic report, 2, 69.
Asdale, 46.
Ashburton, 98, 99.
Ashover, 31.
Associated Portland Cement Manufacturers, 9.
Astbury, 31.
Austin, Godwin, 57.
Ayrshire, 2, 4, 48.

B.

Baggeridge, 13.
Bailey, E. B., 31, 34–36, 38, 40, 41, 58.
Balaam's Wood, 14.
Balderton Hall, 24.
Balmeanach, 34–36.
Balmer Lawn, 84.
Banffshire coast-section, 70–80.
Bank End boring (Cumberland), 85.
Bankend (Lanarkshire), 52.
Bannockburn, 4, 49.
Barrhead, 49.
Barrow, G., 78, 79.
Bartley Green, 15, 16.
Barton, A. E., 85.
Baschurch, 22, 24, 25, 27, 28.
Bath Moor, 51.
Becke, F., 77.
Beer Ferris, 98, 99.
Beinn Donuill, 46.
—— Eagach, 79.
—— na h-Imeilte, 42.
Bell, A., 65.
Bell's Mill, 22.
Belstone, 98, 99.
Ben Aigan, 78.
—— Hiant, 42.
—— More, 41, 58.
Benthall Cross, 24.
Berth, 28.
Berwick Park, 27.
Besford, 25, 28.
Bexley, 7.
Bicton, 27.
Bilmarsh, 24.
Birkhill Wood, 51.
Birmingham, 3, 18, 19, 22.
Black Combe, 29.
Blackheath (Kent), 7.
———— (Staffs), 13.
Blaze Coppice, 25.
Bloody Bay, Tobermory, 37, 38, 43.
Blue Dial Boring, 89.
Blymhill, 16, 20.
Bolton, H., 63.
Bomere Heath, 27.
Bonar Bridge, 46.
Bo'ness, 49.
Booley, 25.
Bosworth, T. O., 34.
Boulton, Prof. W. S., 21.
Bovey, North, 98, 101.
———— Tracey, 98, 99.
Bow, 5.
Boyndie Bay, 76.
Boyne Bay, 76.
Bratton Fleming, 99.
Breach Dingle, 14, 15.
Brentor, 99.
Brettell Lane, 12.
Bridford, 99.
Bridgeford, Great, 21.
Brierley Hill, 12.
Brimington, 30.
Brixham, 99.
Broad Hill, 16.
Broadlands, 61.
Brockenhurst, 81–84.

Digitized by Google

Brockley (Lanarkshire), 54.
Bromehead, C. E. N., 5, 6, 8, 30.
Bromley Lane, 12.
Bromwich Wood, 15.
Broomfields, 27.
Brora, 2, 65.
Buchan, 70, 78, 79.
Buckfastleigh, 98, 100.
Buckie, 72.
Buckland Monachorum, 98, 100.
Buckman, S. S., 63, 65.
Buckpool, 12.
Budeaux, 100.
Burgh Fossil Tree, 4, 39–40.
Burnett, G. A., 29, 31, 34, 38, 40, 42, 48.
Bury Walls, 25.
Bushey, 5.
Butterton and Swynnerton Dyke, 17.

C.

Cabrach, 79.
Cadell, H. M., 52.
Calder Bridge, 29.
Calgary Bay, 43.
California, 14, 18, 22.
Callow Brook, 10, 14.
Cambrian rocks, 2, 10.
Cambridge, 63.
Cambusbarron, 49.
Campbell, J. M., 66.
Campsie, 4, 49.
Cannel Coal report, 2, 65, 68.
Cantrill, T. C., 1, 15, 22, 94.
Carboniferous rocks, 2–5, 12–16, 29–31, 48–55, 65, 85–95.
Carnock, 49, 50.
Carruthers, R. G., 1, 2, 5, 29, 66.
Carsaig, 37, 38.
Castle Hill, 10.
Castleton, 49.
Cement industry, 9.
Central coalfield of Scotland, 2, 49, 69.
Chagford, 98.
Challacombe, 100.
Chatwin, C. P., 63.
Chemical work, 58–62.
Cheshunt, 5–8.
Chetwynd Park, 20.
Chevelstone, 100.
Christow, 100.
Clackmannanshire, 2, 4, 48, 50.
Clamshell Cave, 38, 39.
Clent Hills, 15.
Clive, 25, 26.
Clough, C. T., 34, 48.
Cnoc a' Choire Bhuidhe, 46.
Cobham, 7.
Cockshot Lane, 13.
Cofton railway-cutting, 19.
Collier's End, 2, 6.
Combe Martin, 100.
Cooknell Hill, 18.
Coombe Rock, 8, 9.
Coombes Wood Tube Works, 13.
Copper ore reports, 2.
——— output of Devonshire, 96–102.
Corrie, 49.
——— Burn, 49.
Coryton, 100.
Coton Hill, 28.
Cottrell, H. E. P., 85.
Cotwalton, 17.
Cradley, 9.
Craig, E. H. C., 32, 34, 78.
Craig a' Bhealaich, 45.
Craighead quarry, 61.
Craig Moss, 49.
——— of Boyne, 76.
Craigrie, 51.
Crathie Point, 73, 74.
Crayford, 2, 5, 8.
Creag a' Choineachan, 44.
——— Ghobhair, 45.
Creagan Reamhar, 47.
Cretaceous rocks, 4–6, 9, 36, 62, 63.
Crosby boring, 91.
Cross Green, 27.
Crymmych, 56.
Cullen, 72.
Culrain, 44, 45.
Culverley Green, 84.
Cumberland, 1, 28–29, 85–91.
——— Coal, Power and Chemicals Ltd., 85.
Cunningham, J. H., 70.

D.

Dalmellington, 48.
Dalmore, 46.
D'Arcy boring, 55.
Darenth Wood, 8.
Darlaston, 17.
Dartington, 98.
Dereham, West, 63.
Deveron, River, 61.
Devon Colliery, Clackmannan, 50.
———, River, 50–52.
Devonshire, tin and copper, 96–102.
Dewey, H., 1, 5, 8, 66.
Dibley, G. E., 6.
Dillwyn, R. M., 92.
Dingle, 27.
Dinham, C. H., 4, 29, 44, 48, 49.
Ditherington, 28.
Dixon, E. E. L., 9, 16, 19.

Digitized by Google

Doles Coppice, 17.
Donations to Museum, 66–68.
Douglas coalfield, 5, 48, 52–55.
Doxey Brook, 21.
Dudley, 2, 3, 10–13.
Dun Cul Bhuirg, 32.
Dunmore Hill, 49.
Dunn's Heath, 27.
Durham, 1, 29.
Durn Hill, 74.

E.

Easter Ross, 4, 44–45.
Eastwood, T., 9, 10, 13, 18, 22, 28–30.
Eden, Vale of, 29.
Egghill Dingle, 15.
Eilean Chalbha, 32, 33.
——— Musimul, 43.
Elliot, W. Faber, 81.
Ellowes Park, 3, 11, 12.
Epsom, 59.
Erisgeir, 34.
Erith, 2, 5, 8, 9.
Eve Hill, 10.
Everton, 23.
Eyton, Miss C., 27.
Eyton, 28.

F.

Farragon Hill, 79.
Faskadale, 42.
Faskally House, 79.
Fearnsides, Prof. W. G., 63.
Fenemere, 25, 28.
Fenwick, 48.
Ferriby, North, 63.
Findlater Castle, 73.
Fireclay analyses, 59.
Fireclays report, 2, 59, 69.
Fleet valley, 46, 47.
Flett, J. S., 1–5.
Folkestone, 62, 63.
Ford, 23, 24, 27.
Fordyce Burn, 74.
Formartine, 78.
Fowler, A., 29, 30.
Frankley, 15, 16.
Frankwell, 28.

G.

Gamesley Brook, 21.
Gannow Green, 15.
Garbh Leathad, 47.
Gardner, J. S., 35, 40.
Garren Point, 73.
Gaulrig, 79.
Geikie, Sir A., 31, 39–42, 58.
Georgeham, 100.
Gibson, W., 1, 9, 14.
Glacial and Recent deposits, 2, 3, 7–9, 19–22, 27–29, 42–43, 47, 52, 83–84, 86, 89.
Glasgow, 49.
Glen Cannel, 58.
Gnosall, 20.
Goat Cave, 39.
Goff's Oak, 5.
Gometra, 40, 41.
Gospel End, 13.
Gravel Hill, Shrewsbury, 27, 28.
Gravesend, 5, 9.
Greenly, Dr. E., 66, 69.
Green Street Green, 9.
Gribun, 4, 34, 36, 39.
Grinshill, 25, 26, 28.
Grounds and Newton, Messrs., 81.
Grubenmann, U., 77.
Gunn, W., 35.
Gunther's Wood, 51.

H.

Hagshaw Burn, 52–54.
Haldane, D., 44–48, 51.
Halesowen, 3, 9, 13, 22.
Hampstead, 5.
Harborne, 18, 22.
Harcourt Park, 25.
Hardstoft, 30, 66.
Harford, 100.
Harker, A., 42.
Harkness, R., 70.
Harmer, F. W., 62, 64, 66.
Harmer Hill, 24, 25.
Harrington Docks, 23.
Hartshill, 10.
Hasbury, 14.
Haughton, 17.
Hawkstone, 25, 26, 28.
Hayborough, 91.
Hayley Green, 13.
Heath, 30.
Hencott, 28.
Hennock, 100.
Hensingham, 29.
Hertford, 5–7.
Hertingfordbury, 7.
Highland District, North, 44–48.
——— ———, West, 31–43.
Highlows, 17.
High Offley, 20.
Himley, 12, 18, 22.
Hockley, 18.
Hoddesdon, 6–8.
Hodnet, 22, 28.
Holbrook, 26.
Holloway, 5.

Digitized by Google

Hollymoor Asylum, 15.
Holne, 98.
Horne, J., 70.
Howe, J. A., 1.
Howe of Alford, 79.
Hudleston, W. H., 62.
Hughes, J., 11.
Huntly, 61, 78.

I.

Iddings, Prof. J. P., 38.
Illey Mill, 14.
Ilsington, 98, 100.
Inch Kenneth, 34, 35, 43.
Inchrory, 78.
Inveran, 45.
Inverhouse, 45.
Invershin, 47.
Iona, 3, 31–34, 43.
—— iron ore, 43.
—— marble, 43.
Iron ore reports, 2, 68, 69.
Ironville, 30.
Isle, The, 27, 28.
Ivetsey Bank, 16.

J.

Jameson, R., 70.
Jet report, 65, 68.
Judd, J. W., 4, 34–37, 57, 58.
Jukes, J. B., 11, 13.
Jurassic rocks, 35, 36, 62, 63, 65.

K.

Keillenknowes, 61.
Kenstone, 28.
Kidston, R., 90, 95.
Kilchoan, 36, 42.
Kilninian Church, 40.
Kimmeridge oil-shale report, 65, 68.
Kincardine-on-Forth, 51, 52.
King, W. B. R., 66.
——, W. W., 12, 15.
Kingsbridge, 101.
Kingswinford, 9, 12 18, 21.
Kinlochscridain, 41.
Kirk burn, 50, 51.
Kirksanton, 29.
Kitchin, F. L., 62, 63, 67.
Knightley, 20.
Knighton, 20.
Knowfaulds, 51.

L.

Ladycross Lodge, 83.
Lamentation Hill, 44, 47.
Lamerton, 98, 101.
Lamplugh, G. W., 1, 62, 67.
Lamprophyres, 4, 34, 44, 47.
Lane End, 20.
Lapworth, Prof. C., 14.
Lawneswood, 18.
Leach, A. L., 8.
Lead-ore reports, 2.
Leaton, 22, 27.
Lea valley, 2, 5–8.
Ledsaurich, 46.
Lee, G. W., 2, 4, 35, 36.
Lee Bridge, 25.
—— Brockhurst, 25, 26, 28.
Leighton Buzzard, 62, 63
Lew Trenchard, 101.
Lickey Hills, 2, 10.
Lignite report, 65, 68.
Links Bay, 75.
Littleworth, 20.
Liverpool, 22, 23, 27.
Loch a' Ghobhair, 45.
—— an Lagain, 45.
—— Buie, 41.
—— Don, 36.
—— Leisgin, 47.
—— na Keal, 43.
—— Scridain, 41, 43.
Lockhart, W. S., 66.
Logie Head, 72.
London and South-Eastern District, 2, 5–9.
Longbridge, 22.
Long Crendon, 62.
Longhill Burn, 53.
Long Kettles Wood, 15.
Lord's Wood, 9.
Lustleigh, 101.
Lydford, 98, 101.
Lymington, 82.
———— Rural District Council, 81.

M.

MacAlister, D. A., 96–102.
Macculloch, J., 33, 35, 39, 40.
Macgregor, M., 2, 44, 48, 52, 69.
Maden, J., 28.
Manaton, 98.
Manson, W., 35, 52, 65.
Marchamley, 26.
Marlborough, 101.
Marsden, F., 29.
Maryport, 28, 85–91.
Marystow, 101.
Mary Tavy, 98, 101.
McLintock, W. F. P., 1, 41.
Meall an Fulann, 39.
———— Tarmachain, 42.
—— Uaine, 79.

Digitized by Google

Mearns, 48.
Meavy, 98.
Meikle Fergie Burn, 79.
Menstrie, 50, 52.
Merricks, F., 67.
Merrington Green, 27.
Merritt's Hill, 15.
Middle, 22–25, 28.
Migdale, 45.
Mill burn, 50.
Millom, 29.
Milton Abbot, 101.
Mineral oil report, 2, 65, 68.
——— resources reports, 2, 68.
Moddershall, 17.
Moine rocks, 4, 34, 44–47.
Molland, 98, 101.
Molton, North, 98, 101.
———, South, 102.
Montford Bridge, 27.
Moreton Corbet, 28.
Morvern, 43.
Moston, 28.
Moulding sands, 3, 9, 18.
Mucklow Hill, 13.
Mull, 2, 4, 31–43, 58, 65.
Murchison, Sir R., 26.

N.

Nesscliff, 24.
Ness, Great, 24.
Newcastle-upon-Tyne local office, 1, 29.
Newport (Shropshire), 3, 9, 16, 19.
Newton Abbot, 101.
——— on the Hill, 24.
——— St. Cyres, 101.
Norman Cement Co., 63.
North, F. J., 64.
Northaw, 5.
North Ayrshire coalfield, 48.
——— -Eastern coalfield, 29.
Northfield, 15, 18, 19.
Northumberland, 1, 29.
Norton Bridge, 17.

O.

Offmoor Wood, 14, 15.
Oil borings (Derby and Staffs), 30, 31, 66.
—— ——— (Scottish), 55.
Okehampton, 98.
Oldbury, 12.
Old Hill, 12.
Olive Mount, 23.
Ordovician rocks, 64.
Oriel Road, 23.
Otterspool, 27.
Oulton, 17, 21.
Oykell Valley, 45, 47.

P.

Peach, B. N., 35.
Pembrokeshire, 5.
Peter Tavy, 98, 101.
Photographic work, 65.
Pigeon's Cave, 33.
Pilsen's Wood, 17.
Pim Hill, 23–25.
Plympton St. Mary, 98, 101.
Pocock, R. W., 5, 22, 25, 26, 28.
Pocock, T. I., 8.
Ponder's End, 8.
Poneil Water, 52–54.
Ponfeigh coalfield, 54.
Port an Fhasgaidh, 39.
—— — Fhir-bhreige, 43.
Portknockie, 72.
Portsoy, 60, 74, 75.
Pre-Cambrian rocks, 3, 31–34, 44–46, 70–80.
Prescelly Mountains, 5, 56, 57.
Prescott, 25.
Preston Brockhurst, 25, 26.
——— Montford, 27.
Prestwich, J., 70.
Priest, S., 6.
Prince's Park, 27.
Pringle, J., 62, 63, 67, 90–95.
Pruvost, P., 65.
Publications, 68–69.

Q.

Quinton, 15.

R.

Raasay, 69.
Radley, E. G., 41, 60–62.
Raisin, Miss C. A., 62, 67.
Rankinstone, 48.
Rattery, 101.
Ray, F., 92.
Read, H. H., 44–48, 50, 70–80.
Rednal, 18.
Reed, F. R. C., 64.
Refractory materials reports, 2, 68, 69.
Reid, C., 36, 57.
Reidh Eilean, 38.
Renishaw, 30.
Rheantaoir, 45.
Rhelonie, 45.
Richey, J. E., 4, 31, 36, 40, 42, 48.
Ridge Hill, 18.
Ridgeway, 30.
Robertson, T., 5, 9, 16, 17, 20.
Rock Hall, 25.
Roden, River, 28.
Romsley, 14, 15.
Rosebush, 56.

Digitized by Google

Rothiemay, 60.
Rubery, 2, 10, 14, 15.
Rudha nan Gall lighthouse, 38, 43.
Ruyton, 24.

S.

Sacombe, 5, 7.
St. Columba's Bay, 43.
—— Kenelm's Hall, 15.
—— Stephen (Devonshire), 102.
Salt deposits, 2.
Sandend Bay, 74.
Sands for moulding, 3, 9, 18.
Sanna Bay, 42.
Sapcote, 61.
Scobull Point, 41.
Scotch Brook, Stone, 17, 21.
Scott's Green, 12.
Scoular, J. G., 85.
Scremerston, 29.
Sedgley, 10.
Sefton Park, 23.
Severn, River, 23, 27, 28.
Shanton and Easdale, Messrs., 81.
Shaugh Prior, 102.
Shaver's End, 11.
Shelton Rough, 27.
Sherlock, R. L., 5–7.
Sherwell, 102.
Shields burn, 49.
Shooter's Hill, 28.
Shorne, 2, 7.
Shotton Hall, 24.
Shrawardine, 23.
Shrewsbury, 23, 24, 27, 28.
Shropshire District, 22–28.
Silica-rocks reports, 2, 68, 69.
Silurian rocks, 2, 3, 10–12, 64.
Silver burn, 50.
——— -stone marble, 32.
Sithean Mor, 44, 47.
Skye, 69.
Smethwick, 18, 22.
Smith, B., 1, 3, 28, 29, 67, 85–91, 94.
Smith, R., 8.
Soa, 32.
Sow valley, 21.
Sron Bheag, 36.
Staffa, 4, 38, 39.
Stafford, 9, 21.
Stamp, L. D., 6, 67.
Stanmore, 5.
Stanton, 25.
Stanwardine in the Fields, 27.
Stewarton, 48.
Stirlingshire, 4, 48–50.
Stoke Gabriel, 102.
——— Newington, 5.
Stone (Kent), 9.
——— (Staffs.), 9, 16, 17, 20.
Stonehenge, 5, 56, 57.
Stourbridge, 18, 59.
Stour, River, 22.
Strahan, Sir A., 1, 2, 67, 68, 81.
Straits Green, 12, 13.
Strathbogie, 70, 79.
Strath Carron, 44.
Strathdon, 78.
Strath Fleet, 45, 47.
Summer Hill, 18.
Sutherlandshire, 2, 4, 45–48, 65.
Swanscombe, 2, 6–9.
Swynnerton, 16, 17.
Sydenham Damerel, 98, 102.

T.

Tait, D., 55.
Tavistock, 98, 102.
Tawton, South, 98.
Tertiary Intrusions in Mull, 41.
———— Lavas, 37–41.
———— rocks, 2, 4, 6–7, 9, 36–42, 59, 64, 81–83.
Thomas, H. H., 5, 26, 56, 57, 94.
Tillicoultry, 52.
Tin output of Devonshire, 96–102.
Tipton, 9.
Tobermory, 37, 38.
Tomintoul, 79.
Torridon sediments, 3, 4, 31–33.
Toxteth, 23.
Trachytes, 4, 48.
Trent valley, 20, 21.
Triassic rocks, 2–4, 16–19, 23–26, 29, 35, 85, 86, 89.
Troon, 48.
Tulliallan Forest, 51.
Tullibody, 51, 52.
Turner's Hill, Sedgley, 3, 10, 11.

U.

Uamh nan Calman, 35.
Ugborough, 102.
Ulva, 38, 42.

V.

Van Hise, C., 77.

W.

Walkhampton, 98, 102.
Wallace, T. D., 70.
Wall Heath, 18, 21, 22.
Walton, 23.
Ware, 5, 7.
Warley, 22.
Warren, S. H., 8.

Digitized by Google

Warwickshire and Staffordshire District, 2, 3, 9–22.
Wassel Grove, 15.
Watford, 5.
Watton-at-Stone, 7.
Webscott, 24.
Wellington, 63.
Wem, 22.
Weoley Castle, 19.
Werrington, 30.
West Calder boring, 55.
——— Derby, 23, 27.
——— Ham, 5.
Westmorland, 1, 28–29.
Weston, 25, 26, 28.
West Sands, 73.
Whiston, 24.
Whitbeck, 29.
Whitchurch, 98, 102.
White, H. J. Osborne, 57, 81–84.
Whitehaven, 3, 29.
———————— local office, 1, 28.
Whitehead, T. H., 9, 10, 12, 18,21.
Whyntie Head, 76.
Wilderness, 35.
Wilson, G. V., 2, 31, 37, 38, 41-43.
Wiltshire, 5, 56–57.
Winterbourne, 94, 95.
Wixhill, 26.
Wolborough, 102.
Woodhall Park, 5, 7.
Wordsley, 18, 21, 22.
Wray, D. A., 22, 23, 27.
Wren's Nest, 2, 10, 11.
Wright, W. B., 42.

Y.

Yate boring, 63, 92–95.
Yealmpton, 102.
Yorton Bank, 26.

Z.

Zinc ore reports, 2.

Digitized by Google

SPECIAL REPORTS ON THE MINERAL RESOURCES OF GREAT BRITAIN.

	s.	d.
VOL. I. TUNGSTEN AND MANGANESE ORES. By H. Dewey and C. E. N. Bromehead, B.A., with contributions by T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., and R. W. Pocock, B.Sc. 59 pp. 2 illustrations. Wrapper.....(1915; Edit. 3, *in preparation*)		
VOL. II. BARYTES AND WITHERITE. By R. G. Carruthers, T. Eastwood, A.R.C.S., G. V. Wilson, B.Sc., R. W. Pocock, B.Sc., and D. A. Wray, B.Sc., with contributions by H. Dewey and C. E. N. Bromehead, B.A. 93 pp. 6 illustrations. (1915; Edit. 3, *in preparation*)		
VOL. III. GYPSUM AND ANHYDRITE. By R. L. Sherlock, D.Sc., and B. Smith, M.A.; AND CELESTINE AND STRONTIANITE. By R. L. Sherlock, D.Sc. 64 pp. 4 illustrations. Wrapper. (1915; Edit. 2, 1918)	2	0
VOL. IV. FLUORSPAR. By R. G. Carruthers, R. W. Pocock, B.Sc., and D. A. Wray, B.Sc., with contributions by H. Dewey, and C. E. N. Bromehead, B.A. 39 pp. 2 illustrations. Wrapper .....(1916; Edit. 2, 1917)	0	9
VOL. V. POTASH-FELSPAR, PHOSPHATE OF LIME, ALUM SHALES, PLUMBAGO OR GRAPHITE, MOLYBDENITE, CHROMITE, TALC AND STEATITE (SOAPSTONE, SOAP-ROCK AND POTSTONE), DIATOMITE. By A. Strahan, Sc.D., LL.D., F.R.S.; J. S. Flett, D.Sc., LL.D., F.R.S.; and C. H. Dinham, B.A., with contributions by C. T. Clough, M.A.; T. Eastwood, A.R.C.S.; and A. F. Hallimond, B.A. 43 pp. 3 illustrations. Wrapper. (1916; Edit. 2, 1917)	1	0
VOL. VI. REFRACTORY MATERIALS: GANISTER AND SILICA ROCK, SAND FOR OPEN-HEARTH STEEL FURNACES, DOLOMITE. RESOURCES AND GEOLOGY. 241 pp. 3 plates. 8 text figures. Wrapper .....(1918; Edit. 2, 1920)	7	6
VOL. VII. MINERAL OIL, KIMMERIDGE OIL SHALE, LIGNITES, JETS, CANNEL COALS, NATURAL GAS. ENGLAND AND WALES. 125 pp. 1 plate. 17 text figures. Wrapper. (1918; Edit. 2, 1920)	5	0
VOL. VIII. IRON ORES: HÆMATITES OF WEST CUMBERLAND, LANCASHIRE AND THE LAKE DISTRICT. By B. Smith, M.A. 182 pp. 4 plates. 29 text figures. Wrapper .....(1919)	9	0
VOL. IX. IRON ORES (*contd.*). SUNDRY UNBEDDED ORES OF DURHAM, EAST CUMBERLAND, NORTH WALES, DERBYSHIRE, THE ISLE OF MAN, BRISTOL DISTRICT AND SOMERSET, DEVON AND CORNWALL. By T. C. Cantrill, B.Sc., R. L. Sherlock, D.Sc., and H. Dewey. 87 pp. 7 text figures. Wrapper .....(1919)	3	6
VOL. X. IRON ORES (*contd.*). THE HÆMATITES OF THE FOREST OF DEAN AND SOUTH WALES. By T. F. Sibly, D.Sc. 93 pp. 14 text figures. Wrapper .....(1919)	4	0
VOL. XI. THE IRON ORES OF SCOTLAND. By M. Macgregor, B.Sc.; G. W. Lee, D.Sc.; G. V. Wilson, B.Sc.; with contributions by T. Robertson, B.Sc., and J. S. Flett, F.R.S. 240 pp. 18 text figures .....(1920)	10	0
VOL. XII. IRON ORES (*contd.*). BEDDED ORES OF THE LIAS, OOLITES AND LATER FORMATIONS IN ENGLAND. By G. W. Lamplugh, F.R.S., C. B. Wedd, B.A., and J. Pringle. 240 pp. 8 plates. 12 text figures. Wrapper .....(1920)	12	6

Digitized by Google

	s.	d.
VOL. XIII. IRON ORES (*contd.*). PRE-CARBONIFEROUS AND CARBONIFEROUS BEDDED ORES OF ENGLAND AND WALES. By Sir A. Strahan, K.B.E., Sc.D., LL.D., F.R.S.; W. Gibson, D.Sc.; T. C. Cantrill, B.Sc.; R. L. Sherlock, D.Sc., and Henry Dewey. 123 pp. 3 plates. 10 text figures. Wrapper (1920)	7	6
VOL. XIV. REFRACTORY MATERIALS: FIRECLAYS. RESOURCES AND GEOLOGY. 243 pp. 4 plates. 13 text figures. Wrapper. (1920)	8	0
VOL. XV. ARSENIC AND ANTIMONY ORES. By Henry Dewey, with contributions by J. S. Flett, O.B.E., LL.D., D.Sc., F.R.S., and G. V. Wilson, B.Sc. 59 pp. 1 plate. 2 text figures. Wrapper .....(1920)	3	0
VOL. XVI. REFRACTORY MATERIALS: GANISTER AND SILICA ROCK, SAND FOR OPEN-HEARTH STEEL FURNACES, DOLOMITE. PETROGRAPHY AND CHEMISTRY. By Herbert H. Thomas, M.A., Sc.D.; A. F. Hallimond, M.A., and Ernest G. Radley. 115 pp. 7 plates. 6 text figures. Wrapper .....(1920)	5	0
VOL. XVII. THE LEAD, ZINC, COPPER AND NICKEL ORES OF SCOTLAND. By G. V. Wilson, B.Sc., with contributions by J. S. Flett, LL.D., F.R.S. 159 pp. 2 plates. 16 text figures.....(1921)	7	6
VOL. XVIII. ROCK-SALT AND BRINE. By R. L. Sherlock, D.Sc. 123 pp. 2 plates. 16 text figures. Wrapper .....(1921)	5	0

In course of Publication.

VOL. XIX. LEAD AND ZINC ORES IN THE CARBONIFEROUS ROCKS OF NORTH WALES. By Bernard Smith, M.A. .....

VOL. XX. LEAD AND ZINC: THE MINING DISTRICT OF NORTH CARDIGANSHIRE AND WEST MONTGOMERYSHIRE. By Prof. O. T. Jones, M.A., D.Sc.....

VOL. XXI. LEAD, SILVER-LEAD AND ZINC-ORES OF CORNWALL, DEVON AND SOMERSET. By Henry Dewey .....

VOL. XXII. LEAD AND ZINC ORES OF THE LAKE DISTRICT. By T. Eastwood, A.R.C.S. .....

VOL. XXIII. LEAD AND ZINC ORES IN THE PRE-CARBONIFEROUS ROCKS OF WEST SHROPSHIRE AND NORTH WALES. By B. Smith and H. Dewey .....

In Preparation.

VOL. . LEAD AND ZINC ORES OF NORTHUMBERLAND, &C. By Stanley Smith, B.A., D.Sc. .....

VOL. . LEAD AND ZINC ORES OF THE PENNINE DISTRICT. By R. G. Carruthers .....

VOL. . COPPER ORES OF ENGLAND AND WALES. By Henry Dewey .....

VOL. . REFRACTORY MATERIALS: FIRECLAYS. CHEMISTRY AND PHYSICAL TESTS. By F. R. Ennos, B.A., and other contributors .....

VOL. . CANNEL COALS, SHALES AND MINERAL OIL OF SCOTLAND .....

Digitized by Google

Summary of Progress of the Geological Survey of the United Kingdom.

	Price.		Price.
For 1897	*Out of print*	For 1902	*Out of print*
„ 1898	1*s.* 0*d.*	„ 1903	1*s.* 0*d.*
„ 1899	1*s.* 0*d.*	„ 1904	1*s.* 0*d.*
„ 1900	1*s.* 0*d.*	„ 1905	*Out of print*
„ 1901	1*s.* 0*d.*		

Summary of Progress of the Geological Survey of Great Britain.

	Price.		Price.
For 1906	*Out of print*	For 1914	1*s.* 0*d.*
„ 1907	*Out of print*	„ 1915	1*s.* 0*d.*
„ 1908	1*s.* 0*d.*	„ 1916	1*s.* 6*d.*
„ 1909	*Out of print*	„ 1917	2*s.* 0*d.*
„ 1910	*Out of print*	„ 1918	2*s.* 6*d.*
„ 1911	*Out of print*	„ 1919	2*s.* 6*d.*
„ 1912	*Out of print*	„ 1920	
„ 1913	1*s.* 0*d.*		

Recent Publications.

Memoirs.

	s.	*d.*
A Short Account of the Geology of the Isle of Wight. By H. J. Osborne White, F.G.S.	10	0
The Water Supply of Buckinghamshire and of Hertfordshire from Underground Sources. By W. Whitaker, B.A., F.R.S.	16	0
The Water Supply of Norfolk from Underground Sources. By W. Whitaker, B.A., F.R.S.	10	0

Maps.

One-inch scale, England and Wales—	
Sheet 269 (Windsor and Chertsey)	each, 2 0
Sheet 228 (Haverfordwest), Drift Edition	
Sheet 228 (Haverfordwest), Solid Edition	
One-inch scale, Scotland—	
Sheet 53 (Ben Nevis)	each, 3 0
Sheet 81 (Applecross)	
Four Miles to one-inch scale, Scotland—	
Sheet 6, Caithness (part of), Thurso and Wick	each, 3 0
Sheet 13, Argyllshire (part of), Knapdale, Jura, Islay and Colonsay	

Other Memoirs in course of Publication.

Geology of the South Wales Coalfield—Part XIII.—Country around Pembroke and Tenby

Geology of South London

Water Supply of Cambridgeshire, Huntingdonshire and Rutland

Economic Geology of the Central Coalfield of Scotland—Area IX.—including the Districts of Carluke, Strathaven and Larkhall

Description of Arthur's Seat Volcano (Second Edition)

Printed under the authority of His Majesty's Stationery Office
By Eyre and Spottiswoode, Ltd., East Harding Street, E.C. 4,
Printers to the King's most Excellent Majesty.

Digitized by Google

Digitized by Google

14 DAY USE
RETURN TO DESK FROM WHICH BORROWED
EARTH SCIENCES LIBRARY

This book is due on the last date stamped below, or
on the date to which renewed.
Renewed books are subject to immediate recall.

LD 21–50*m*-6,'60
(B1321s10)476

General Library
University of California
Berkeley

Digitized by Google

Digitized by Google

Digitized by Google